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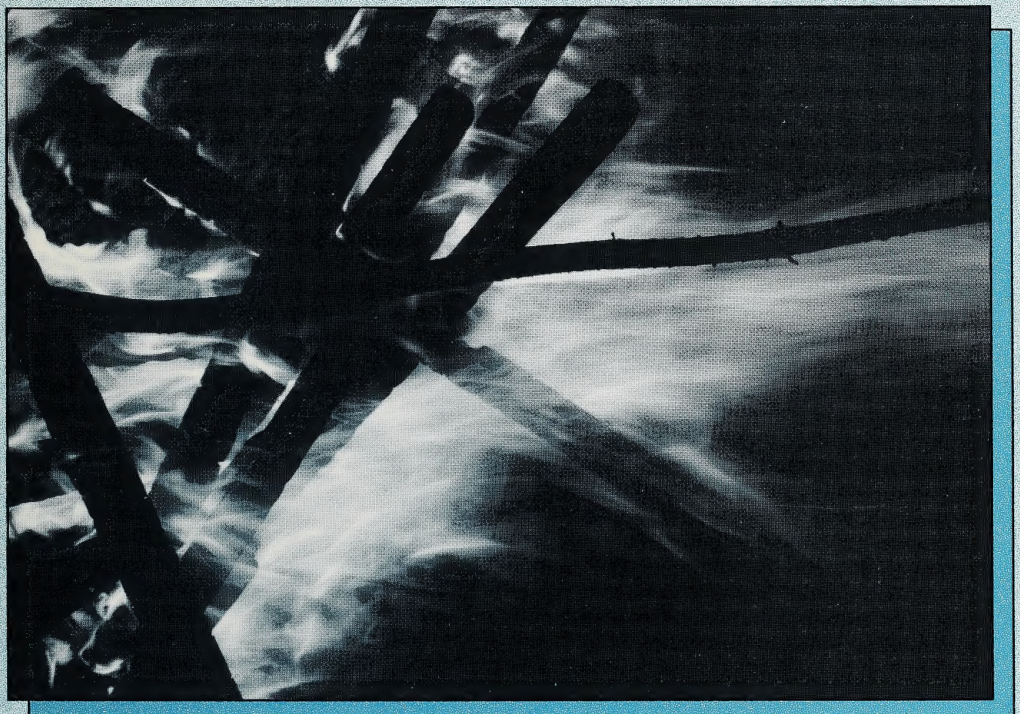

MODULE 4:
TEMPERATURE AND HEAT

Distance Learning

Alberta EDUCATION

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ACKNOWLEDGEMENTS

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Student Module
Module 4
Temperature and Heat
Alberta Distance Learning Centre
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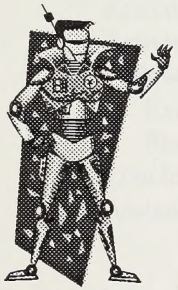

Welcome to Module 4!

We hope you'll enjoy your study of Temperature and Heat.

To make your learning a bit easier, a teacher will help guide you through the material.

So whenever you see this icon,

turn on your audiocassette and listen.

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OVERVIEW

"How hot is hot?" "How cold is cold?" For most people, the answers to these questions are found in the weather. But there is more to hot and cold than just the weather.

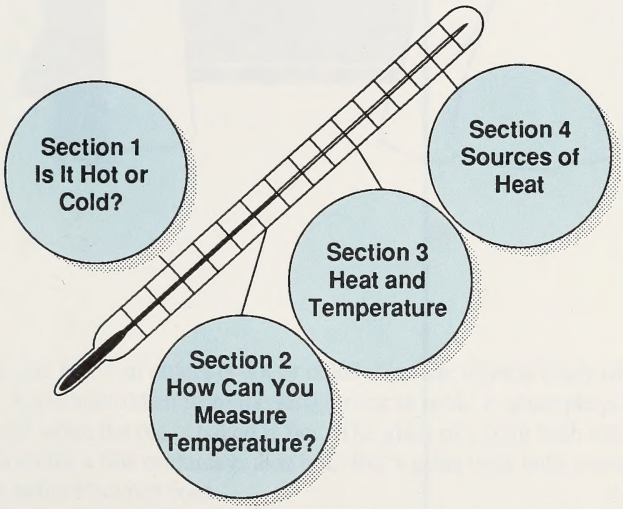
To the inquiring mind, solving one question usually leads to a number of other questions. If *hot* means having heat, and *cold* means a lack of heat, then you could ask:

"What is heat?"
"How does one measure heat?"
"Where does heat come from?"
"What is temperature?"
"How does one measure temperature?"

Can you think of other questions?

In this module you will discover the answers to these and other questions. You will discover how scientists do their work – by observing, asking questions, performing experiments, and providing explanations for their observations.

Temperature and Heat



Caution

A number of activities in this module involve the use of hot plates or flames. These activities should all be done with the advice and supervision of the learning facilitator.

Evaluation

Your mark in this module will be determined by your work in the Assignment Booklet. You must complete all assignments. In this module you are expected to complete four section assignments.

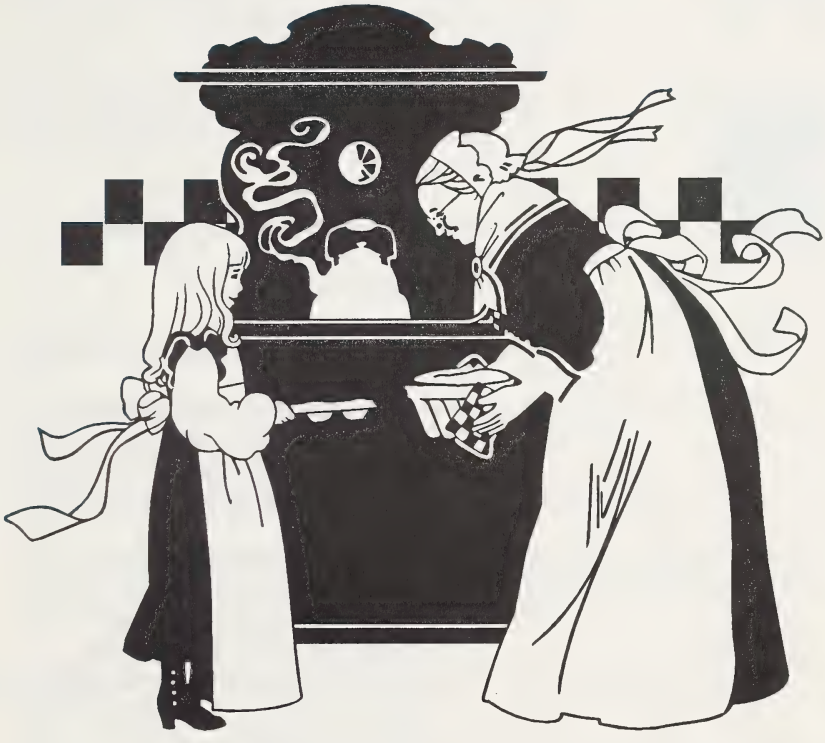
The assignment breakdown is as follows:

Section 1 Assignment	**12%**
Section 2 Assignment	**32%**
Section 3 Assignment	**26%**
Section 4 Assignment	**30%**
TOTAL	**100%**

Section

1

Is It Hot or Cold?



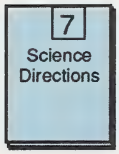
How can you tell if an object is hot or cold? You use objects made of glass every day. A glass jar taken from the refrigerator is cold. A glass pie plate taken from the oven when the pie is baked is hot. The glass of a light bulb that has been turned on for a few minutes is also hot. But a glass light bulb stored in a cupboard is neither hot nor cold.

You know from experience when things are too hot to touch. But when you are handling objects that are cool enough to touch, how do you judge how hot or how cold they are? You will find out in this section.

Activity 1: Estimating Temperatures

Temperature: a measurement of the average energy of a substance or how hot or cold it is

You likely know what the predicted **temperature** is for today. If not, by going outside you can quickly tell whether or not you will need to wear a jacket to be comfortable. But how wide a range of temperatures can you estimate? This activity will help you find out.



In this activity you will see how accurately you can estimate how hot or cold objects are. It is adapted from the information on page 198 of *Science Directions 7*. Refer to the textbook if you want additional background information.

You will need the following materials:

- 14 index cards

Follow the instructions and answer the questions.

- Copy each item from the following list onto a separate index card.

  – temperature of boiling water (at sea level)
  – body temperature of a healthy person
  – hot tea
  – a comfortable room temperature
  – ice cream
  – the lowest temperature possible
  – comfortable bath or shower water
  – temperature of air in oven when a roast is cooking
  – coldest air temperature recorded on Earth
  – surface of the Sun
  – hottest air temperature recorded on Earth
  – temperature at which water freezes
  – air in a refrigerator
  – interior of the Sun

- Arrange the cards into three piles – hot temperature, medium temperature, and cold temperature.

- Put the cards in each pile in order, estimating the temperature from coldest to hottest.

1. Record the order you decided upon in the following chart.

Estimated Order from Hottest to Coldest

hottest

• _____	• _____
• _____	• _____
• _____	• _____
• _____	• _____
• _____	• _____
• _____	• _____
• _____	• _____ coldest

- Find the actual temperature of each item. Do this by library research or by seeing your learning facilitator for the actual temperatures.
- Write the actual temperatures on the back of the index cards for each item.
- Turn the index cards over and, without looking at the back, try to put them in temperature order again. How well did you do? Keep trying until you can put them all in order.

2. In the following chart, list the items again in the actual order from hottest to coldest.

Actual Order from Hottest to Coldest

hottest

• _____	• _____
• _____	• _____
• _____	• _____
• _____	• _____
• _____	• _____
• _____	• _____
• _____	• _____ coldest

Check your answers with your learning facilitator.

7 Science Directions

Activity 2: Hot or Cold?

Read page 196 of *Science Directions 7* and examine the photograph on that page. See how the glassworker has learned to tell, by looking at the glass, when it is hot enough to be shaped.

Now look at the objects in the photograph on page 197 of the textbook. How could you estimate the temperature of the objects shown? You probably have noticed that metal objects often feel colder than wood or plastic objects. Are they really colder?

When you have a shower or bath, you feel the water with your hand or foot before climbing in. By doing this, you estimate if the water is too hot or too cold. But how accurate are your senses? Can your sense of touch be fooled? This activity will show you that your sense of touch is not always reliable. Complete the steps as indicated; then answer the questions that follow.

Materials You Need

- a bowl of hot tap water
- a bowl of cold tap water
- a bowl of lukewarm tap water

Steps to Follow

Step 1: Put one hand in the hot water. The water should not be so hot that it hurts you.

Step 2: At the same time, put your other hand in the cold water.

Step 3: Keep your hands in the water for at least one minute.

Step 4: Take your hands out of the hot and cold water and put them both in the lukewarm water.

Questions to Answer

1. How did the hand that was in the hot water feel when it was put in the lukewarm water?

   _____

2. How did the hand that was in the cold water feel when it was put in the lukewarm water?

   _____

3. a. Is touch a reliable indicator of temperature?

_____

b. Why or why not?

_____

_____

Discuss your answers with your learning facilitator.

Activity 3: Increasing Accuracy

From the activities you have done, you probably learned that it is difficult to estimate the temperature of objects using only your senses. It is often important to know how hot or cold something is. Doctors need to know what your body temperature is when you are ill. French fries will either taste soggy or burnt if cooked at the wrong temperature. Oil refining and the making of steel must be done at specific temperatures. You can ruin the engine in a car if you continue to drive it when it is too hot. You need a tool that can tell you how hot or cold an object is.

Thermometer: a device to measure temperature

An Italian scientist, Galileo Galilei, who lived in the 1600s, invented the first device for measuring temperature. He called this device a **thermometer**, from *thermo* meaning heat and *meter* meaning measuring device. His first thermometer contained mostly air.

7 Science Directions

Read pages 205 and 206 of the textbook. Have a look at the photograph of Galileo Galilei and the air thermometer he invented. There is a small amount of liquid in the thermometer. When the temperature rises, the air in the thermometer expands. The air pushes against the small amount of liquid, causing it to rise. The level of the liquid can thus be used to give a temperature reading.

Most of the thermometers you are familiar with use liquid instead of air for measuring temperatures. You will use a liquid thermometer in this activity to estimate the temperature of water samples.

Uncalibrated: without a numerical scale

You will use an **uncalibrated** thermometer. That means that there are no lines or numbers on the thermometer. By using the uncalibrated thermometer you will be able to estimate the temperatures of things without using numbers. This will help you understand how a thermometer works, and it will help you understand more about what temperature means.

Materials You Need

- uncalibrated thermometer
- four heat resistant glasses, beakers, or cups
- water
- ice
- kettle to boil water in
- masking tape
- marking pencil

Steps to Follow

Step 1: Put a strip of masking tape on the uncalibrated thermometer so that it is along the glass tube. You will mark the temperature of the samples on the masking tape.

Step 2: Half fill Glass 1 with water; then add some ice cubes. Set it aside until later.

Step 3: Fill Glass 2 with cold water from a tap.

Step 4: Fill Glass 3 with hot water from a tap.

Step 5: Fill Glass 4 with boiling water from a kettle.

Step 6: Put the thermometer into Glass 4. When the liquid in the thermometer quits moving, mark its level on the masking tape.

Step 7: Repeat step 6 for the other three glasses. Each time you do this, make a mark on the masking tape to record the level the thermometer reached.

Questions to Answer

1. a. Which glass contained the hottest water?

_____

_____

b. How was this shown by the thermometer?

_____

_____

2. a. Which glass contained the coldest water?

_____

_____

b. How was this shown by the thermometer?

_____

_____

3. List the glasses from hottest to coldest.

hottest _____

_____

_____

coldest _____

4. Why is a thermometer more accurate than using your senses to estimate temperature?

_____

_____

_____

_____

Check your answers with your learning facilitator.

Activity 4: Calibrating a Thermometer

By using the uncalibrated thermometer you could demonstrate which glass of water was colder or hotter by marking the level on the thermometer. You could also take the thermometer outside every day for a week, mark the temperature on the masking tape, and then list the days of the week from hottest to coldest.

But you still would not know how hot or how cold each day was. You would need a scale with numbers to know how hot something is.

Galileo faced the same problem. He could compare the temperature of things with his thermometer, but he could not communicate to other people what he was measuring. A hot bath and a hot cup of tea are not the same temperature, even though you call them both "hot." Similarly, a very cold day is a different temperature than a very cold glass of water, yet both are described as "very cold." This new problem involves knowing the temperature and being able to communicate it to others so that they clearly understand what you mean when you describe the temperature.

You were able to calibrate your force meter by hanging weights on from the force meter and then marking a scale in units called newtons. At first you may be tempted to put a new piece of masking tape on the thermometer, draw some equally spaced lines for a scale, and then number them. But how do you know which line to call *0* or *100*?

Actually you could call any line 0 and any other line 100. But developing your own scale will not help you communicate to other people a temperature reading that they will understand.

Anders Celsius, a Swedish scientist, solved this problem in 1742. To make his scale, Celsius started with an uncalibrated thermometer. He decided to make the freezing point of water as zero, and to mark the boiling point of water as 100. Then he divided the space between these two marks into 100 divisions calling each division one degree. Temperatures between 0°C and 100°C could then be marked on the scale. The ninth General Conference of Weights and Measures officially named the scale the Celsius scale in 1948, in honour of Anders Celsius.

If you tell a friend that it is 30°C outside, your friend will know what you mean. You both are speaking the same temperature language. Most people in the world use the Celsius scale, so measuring and recording temperatures using the Celsius scale makes sense. If most people in the world used a different scale, it would make sense for you to use that scale.

Calibrate: to mark a scale of units on a measuring device, such as degrees on a thermometer

In science and in everyday life it is important to be able to communicate clearly with others. You will now **calibrate** your thermometer and learn how scientists developed a temperature scale.

To make a temperature scale you must start with a thermometer. You will use the uncalibrated thermometer that you used for the previous activity. Remember that the liquid rises up the tube as it gets hotter and moves back down the tube as it gets colder.

In order to mark degrees for the scale, two fixed points are needed. You will use the same fixed points as Anders Celsius used. The freezing point of water will be your lower fixed point, and the boiling point of water will be your upper fixed point.

Numbers are given to the fixed points, and the space between the two points is divided into equal divisions called degrees. In the Celsius scale the freezing point of water has been given the value of 0, and the boiling point of water has been given the value of 100. There are 100 degrees between the two reference points. You will only mark your scale with the numbers 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100.

Do either Part A or Part B.

Part A involves developing your own method to calibrate a thermometer using the Celsius scale.

Part B involves following directions provided to calibrate a thermometer using the Celsius scale.

Part A: Calibrating Your Thermometer by Your Own Method

Note: You do not need to complete Part A if you wish to do Part B.

How can you make your uncalibrated thermometer into a calibrated thermometer? In this part of the activity, you must think about how you would change your thermometer so you could measure the temperature in degrees.

How would you go about doing this? What would you do first? What would you do next? If you need help, you may want to reread and think about what Anders Celsius did.

Follow the instructions and answer the questions.

1. After you have thought about it, make a list on a separate piece of paper of the steps you would use. When you are sure that you have all the steps you need, in suitable order, write them in the following space.

2. Show your proposed method to your learning facilitator and make any changes that are suggested.

3. Collect your materials.

4. Calibrate your thermometer.

5. What is the temperature of the room you are in?

_____

Discuss your answers with your learning facilitator.

Part B: Calibrating Your Thermometer by Following Directions

Note: You do not need to complete Part B if you have already done Part A.

Materials You Need

- uncalibrated thermometer
- masking tape
- marker
- water
- ice cubes
- beaker or cooking pot
- beaker or drinking glass
- oven mitt
- ruler
- hot plate or stove

Steps to Follow

Step 1: Put a strip of masking tape on the uncalibrated thermometer so that you can mark a scale along the glass tube.

Step 2: Put some ice cubes in a beaker or drinking glass. Set the beaker aside to let the ice cubes partially melt.

Step 3: Boil water in the other beaker or cooking pot. Using an oven mitt, hold the thermometer in the water until the liquid in the thermometer stops rising. This is the boiling point of water.

Step 4: Put a mark on the thermometer to show the highest level of liquid in the tube. Write *100* beside this mark.

Step 5: When the ice in the first beaker has started to melt, hold the thermometer in the water against the ice so that it measures the temperature of the ice as it melts. This is close to the freezing point of water.

Step 6: You will find that the liquid in the thermometer stays in the same place; mark this place on the masking tape. Write *0* beside this mark.

Step 7: Using the ruler, measure the distance between the two markings on the thermometer. Divide the distance by ten. Use this answer to mark ten spaces between the *0* and the *100*.

Step 8: Label the new marks *10, 20, 30, 40, 50, 60, 70, 80, 90,* and *100*.

Step 9: Measure the temperature of the room you are in.

6. What is the temperature of the room you are in?

_____

Discuss your answers with your learning facilitator.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

The first question in the section was "How can you tell if an object is hot or cold?" You tried to estimate temperatures but found out that your senses were not reliable. Your right hand gives you a different answer than your left hand gives, such as you found in Activity 2.

You then used a thermometer without numbers, but you quickly discovered that a temperature scale is needed to communicate with other people. The Celsius scale is useful because most of the world uses this scale.

7 Science Directions

This Extra Help activity is based on the information given on page 207 of *Science Directions 7*. It will help you understand the Celsius scale better. You will need a laboratory thermometer (with a scale from below 0°C to above 100°C).

Caution

A glass thermometer breaks easily. Handle it carefully.

1. Examine the thermometer carefully. Notice where the glass is thick and where it is thin. Draw a diagram of the thermometer in the box on the right.

   Add the following labels on your diagram:

   - liquid (coloured alcohol)
   - bore (the fine opening through which the liquid moves)
   - thick glass
   - thin glass
   - bulb (storage space for the liquid)
   - scale
   - freezing point of water (0°C)
   - boiling point of water (100°C)
   - comfortable room temperature (21°C)
   - average normal body temperature (37°C)

2. What happens to the temperature reading if you place your hand around the middle of the thermometer?

   _____

   _____

3. What happens to the temperature reading if you place your hand around the bulb?

4. The bulb is considered to be an important part of a liquid thermometer. Give a possible reason why.

5. a. Which part of the thermometer has the thinnest glass?

   b. Why do you think it is made this way?

6. How many Celsius degrees are there between the freezing point of water and the boiling point of water?

7. Why do you think that coloured alcohol was used in the thermometer instead of coloured water?

8. Why should you not put this thermometer into a liquid at 300°C?

_____

_____

_____

_____

Check your answers with your learning facilitator.

Enrichment

Temperature is how hot or cold something is, as measured on a particular scale. Instruments that measure temperature are called thermometers. Thermometers are calibrated by marking a scale on the thermometer. The two most common temperature scales used on thermometers are Celsius and Fahrenheit.

1. Use reference books to find the following temperatures for the Celsius scale and for the Fahrenheit scale (developed by Gabriel Fahrenheit). Fill in the following chart.

	Temperature in Degrees Celsius	Temperature in Degrees Fahrenheit
temperature at which water freezes		
temperature at which ice melts		
temperature at which water boils		
temperature of a hot summer day		
temperature of a cold winter day		
comfortable room temperature		
average normal body temperature		

a. Who was the Fahrenheit scale named after?

_____

_____

b. What two fixed points were used when the Fahrenheit scale was first made?

low point: _____

high point: _____

Changing Celsius Readings to Fahrenheit Readings

To change a temperature measurement from the Celsius scale to the Fahrenheit scale you can use the following equation.

$$F = 1.8 \times C + 32$$

For example, if you wanted to change a measurement of 30°C to a reading in Fahrenheit

- first multiply 30 by 1.8 to get an answer of 54
- next, add 32 to the answer 54 to get 86

This means that 30°C is the same temperature as 86°F.

2. Change each of these Celsius measurements to Fahrenheit measurements.

a. The freezing point of water is 0°C or _____°F.

b. The boiling point of water is 100°C or _____°F.

c. Average normal body temperature is 37°C or _____°F.

Changing Fahrenheit Readings to Celsius Readings

To change a temperature measurement from the Fahrenheit scale to the Celsius scale you can use the following equation.

$$C = \frac{5}{9} \times (F - 32)$$

For example, if you wanted to change a measurement of 212°F to a reading in Celsius

- first subtract 32 from 212 to get an answer of 180
- next, multiply your answer (180) by 5 to get 900
- then, divide this answer (900) by 9 to get your final answer of 100

This means that 212°F is the same temperature as 100°C. Is this the answer you got for question 2.b.?

3. Change each of these Fahrenheit measurements to Celsius measurements.

   a. Comfortable room temperature is 70°F or _____°C.

   b. A hot summer day is 86°F or _____°C.

   c. A very cold winter day is – 40°F or _____°C.

Check your answers with your learning facilitator.

Conclusion

In this section you have learned why a temperature scale is needed. There are many situations in which you need to communicate temperatures. You do this by using a temperature scale that is commonly known. The most common temperature scale is the Celsius scale. You should now be able to answer the question, "How can you judge how hot or how cold something is?"

Assignment Booklet

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 1.

Section

2

How Can You Measure Temperature?

Section 1 showed that it is difficult to estimate temperatures accurately by using only your senses. By using thermometers with temperature scales, you can measure the relative hotness or coldness much more reliably.

In this section you will be introduced to several changes that occur in matter when it is heated or cooled. You will find out how physical properties, such as the state of matter and colour, can be used to infer the temperature of a substance. Changes that occur when solids, liquids, or gases are heated or cooled can be measured and calibrated. Once calibrated these changes in matter can be used to measure temperature in various ordinary and specialized situations.

Activity 1: States of Matter

7 Science Directions

Read States of Matter and see the cartoons on page 199 of *Science Directions 7*. Also examine the drawings of the containers showing the characteristics of gases, liquids, and solids.

Volume: the amount of space occupied by a solid, liquid, or gas; the amount of space in a container

State of Matter: one of three states (gas, liquid, or solid) that all substances can be grouped into

Gas: a state of matter that has no definite shape or volume A gas takes the shape of its container and spreads out to fill the container it is put in.

Compressed: squeezed; pushed together

Liquid: a state of matter that has a definite volume but no definite shape

Solid: a state of matter that has a definite volume and shape

In the textbook reading you were told how it helps to know the meaning of **volume** in order to understand how a gas, a liquid, and a solid differ. One way to describe a **state of matter** is to compare what happens when it is put into a container.

A **gas** takes on the volume and shape of any container it is put into; a gas can flow. When you fill a container with gas, you must cap the container or the gas will escape. The volume of gas can change. In a small container, it is **compressed** so that it will all fit. When you pump air into a tire, you are squeezing in more air. If there is a tire leak, the air spreads out. Air, oxygen, nitrogen, and helium are all examples of gases.

A **liquid** has a set volume but it has the same shape as the container it is in; a liquid can also flow. Liquids cannot be compressed; you cannot fit more into a container once it is full. A liquid flows to take the shape of its container but does not change its volume – it does not spread out to fill a container. Examples of liquids are water, milk, oil, alcohol, and apple juice.

A **solid** has a set volume and shape; it cannot flow. A solid does not change shape; it cannot be compressed. A solid keeps its shape. Solids do not flow to take the shape of their containers. Examples of solids are ice, steel, and wood.

Remember all substances can be grouped into one of the three states of matter. Matter can be a solid (like ice), a liquid (like water), or a gas (like water vapour).

1. What are the three states of matter?

   - _____
   - _____
   - _____

2. Which states of matter can flow?

   _____

   _____

3. Which states of matter cannot be compressed?

4. What does volume mean?

5. What does compressed mean?

Check your answers with your learning facilitator.

Activity 2: Changes in Matter

Long ago, before the invention of modern techniques and instruments, people had to rely on their experiences and their common sense to solve problems. A very common problem to be solved was how to determine how hot or cold something was – food to be eaten, liquids to be drunk, or objects to be handled. People had to rely on their senses to tell them what they needed to know.

If an object was too hot to touch, they might burn themselves.

If their food was too cold, they might not enjoy their meal.

Matter changes when it is heated or cooled. By looking for these changes, you can estimate how hot or cold something is. These changes can take many different forms. Consider the following examples.

Example 1

When an iron rod is placed into a flame, the colour of the rod will slowly change from dark brown, to red, to orange, and finally to white. Changes in colour can often help you estimate temperature.

Example 2

Ice cubes in a pot on the stove will change from a solid to liquid. If heated long enough, bubbles of gas form in the liquid. Changes in the state of matter (solid, liquid, or gas) are a good indicator of temperature.

Example 3

A chocolate bar stored in the refrigerator will become quite hard and rigid. If taken out of the refrigerator, it will become soft and flexible. Hardness is more evidence of how hot or cold something is.

In summary, three things that can be used to tell if an object is hot or cold are

- colour
- state of matter
- hardness

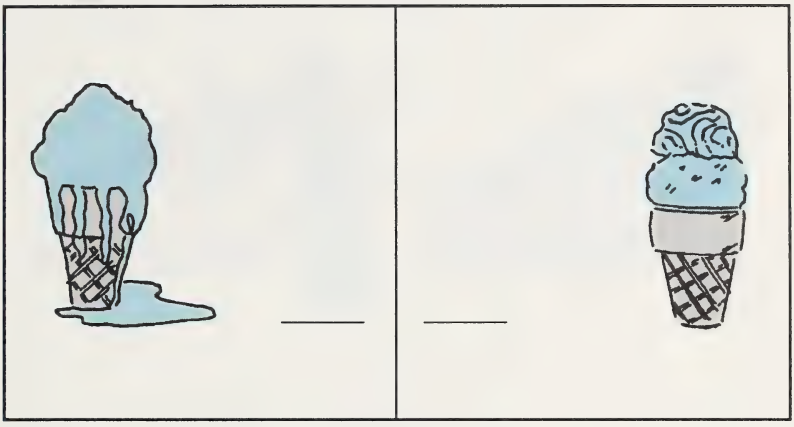
There are other changes that can be used to tell if an object is hot or cold. The key is to look for such changes.

This activity will help you to discover physical properties that can be used to determine if an object is hot or cold.

For the following situations, an object has been pictured twice. In each situation you are to identify when the object is hot and when it is cold. Write *hot*, *warm*, or *cold* in each space. This should be very easy to do.

Once you have done this, briefly describe what evidence you used to interpret the temperature in each situation. If there is more than one kind of evidence, be sure to describe all the evidence you see.

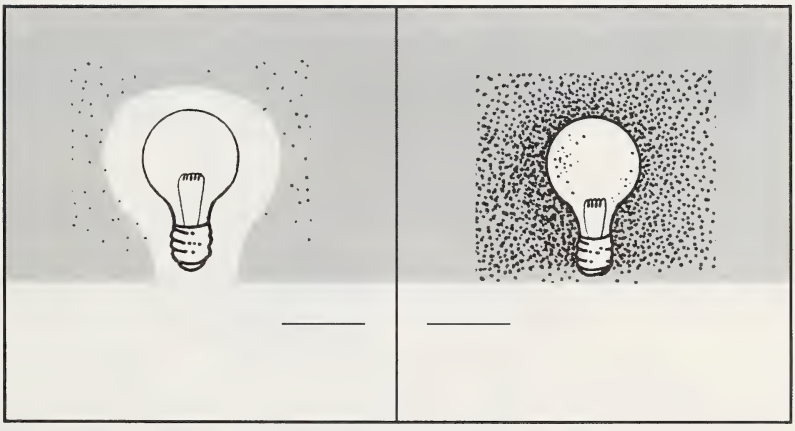
1. Ice Cream Cones



Evidence: _____ Evidence: _____

_____ _____

2. Light Bulbs



Evidence: _____ Evidence: _____

_____ _____

3. Candles

_____

_____

Evidence: _____

_____

_____

Evidence: _____

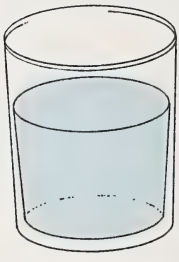
_____

_____

4. Drinking Glasses

_____

_____



Evidence: _____

_____

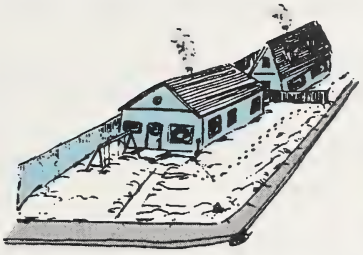
_____

Evidence: _____

_____

_____

5. Weather



_____

_____

Evidence: _____

_____

_____

Evidence: _____

_____

_____

Check your answers with your learning facilitator.

Activity 3: Heating and Cooling Gases

In Activity 2 you learned that it is possible to tell whether an object is hot or cold by observing a change. You looked for changes in colour, state of matter, and hardness or softness. One other change is very important.

Air is a mixture of gases. The main gases that make up the air you breathe are nitrogen, carbon dioxide, and oxygen. Since air is easy to use, you will be using it in this activity to test what happens to a gas when its temperature changes.

Materials You Need

- round balloon
- string
- ruler
- felt marker

Steps to Follow

Step 1: Blow up the balloon until it is full of air.

Step 2: Take the piece of string and wrap it around the balloon to measure the distance around the balloon (its circumference).

Step 3: Use the felt marker to draw a line around the balloon where the string is wrapped.

Step 4: Mark the string at the point where the string has completely wrapped around the balloon.

Step 5: Unwrap the string and measure the circumference using a ruler. Record this measurement.

Step 6: Put the balloon in the refrigerator or freezer (or outside if it is cold) for five minutes.

Step 7: Remove the balloon from the refrigerator; then measure the circumference again. Record this measurement.

Step 8: Hold the balloon carefully in a sink and run hot water over it for one minute.

Step 9: Measure the circumference again and record the measurement.

Observations

Condition of Balloon	Circumference (cm)
room temperature	
refrigerator/freezer temperature	
hot water temperature	

Questions to Answer

1. What happens to the circumference of the balloon when it is cooled?

2. What happens to the circumference of the balloon when it is heated?

_____

_____

3. Write a statement about what the size of the balloon can show you about the temperature.

_____

_____

_____

4. How could a balloon be used as a thermometer?

_____

_____

_____

_____

Discuss your answers with your learning facilitator.

Activity 4: Heating and Cooling Solids

As a balloon gets hotter, its circumference gets larger. This is because the air (a gas) inside the balloon expands (increases its size) when it is heated.

Also, as a balloon gets colder, its circumference gets smaller. This is because the air (a gas) inside the balloon contracts (decreases in size) when it is cooled.

You have only tried this with air, but scientists have demonstrated that all gases **expand** when heated and **contract** when cooled. This is the reason that Galileo's air thermometer worked. Do you remember how it works? If not, examine the photograph of Galileo's air thermometer shown on page 206 of *Science Directions 7* and review how it operates.

Expand: to increase in volume

Contract: to decrease in volume

What about solids? Is there any evidence that solids expand when heated and contract when cooled?

7 Science Directions

Turn to page 202 of *Science Directions 7*. Read Heating and Cooling Solids, and examine the illustrations shown.

A ball and ring apparatus is often used to demonstrate that solids expand when heated and contract when cooled. The textbook illustration shows that at room temperature the ball will easily pass through the ring. This shows that the ball is smaller than the ring. However, once the ball is heated by a hot flame, it cannot be pushed through the ring. This shows that when the ball is heated it is larger than the ring. The explanation is that the ball expanded when heated. If the ball is placed under cold water, it contracts and then will again fit through the ring.

Solids expand and contract very little compared to gases. But if you look carefully, you will see other evidence. For example, railway tracks have gaps in them. In hot weather, the metal tracks expand and move closer together. In cold weather, the metal tracks contract and move apart. Power lines are hung so that they can expand and contract as the temperature changes. The sag allows the wires to get shorter (contract) without pulling apart in cold weather.

Bimetallic strip: two strips of different metals bonded together

One of the most interesting demonstrations of solids expanding and contracting is heating and cooling a bimetallic strip. Different metals contract and expand at different rates. A **bimetallic strip** is made from two different metals bonded together. When it is heated it bends. This happens because one of the two metals in the strip expands more than the other. You can use this effect to make a solid thermometer.

Do either Part A or Part B.

Part A involves using a bimetallic strip to see how it could be used to make a thermometer. All students are encouraged to do Part A if materials are available. Be careful when using an open flame. Part A should be done under the supervision of a learning facilitator.

Part B involves answering the same questions as in Part A after interpreting diagrams of what happens to a bimetallic strip when it is heated in a flame and when it is cooled under running water.

Part A

Materials You Need

- bimetallic strip attached to a handle
- heat source with a flame

Steps to Follow

Step 1: Hold the bimetallic strip in a flame. Record what you observe in the observations chart by describing or drawing what you see.

Step 2: Hold the bimetallic strip under cold running water. Record what you observe in the observations chart by describing or drawing what you see.

Observations

Bimetallic Strip in a Flame

Bimetallic Strip under Cold Running Water

7 Science Directions

Questions to Answer

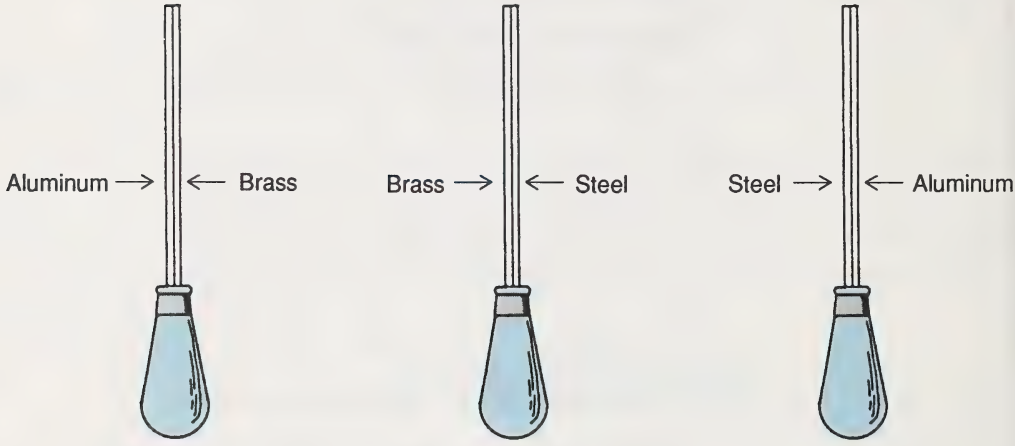
1. Examine the drawing of the scale near the bottom of page 210 of *Science Directions 7*. Explain how you could hold the bimetallic strip so that it could be used with the scale shown.

_____

_____

_____

2. Assume that you are responsible for making bimetallic strips. You discover that aluminum expands more than brass, and brass expands more than steel. You make three bimetallic strips as shown.



a. Draw arrows on the diagrams to show which way each strip will bend when heated.

b. Which strip will bend the most?

_____

c. Explain why you think so.

_____

_____

7 Science Directions

3. An oven thermometer uses a coiled bimetallic strip. Examine the drawing of an oven thermometer on the bottom right corner of page 215 of *Science Directions 7*. There are two metals in the bimetallic strip: brass and iron. When heated, the brass expands more than the iron.

   How do you think this thermometer works?

   _____

   _____

   _____

Check your answers with your learning facilitator.

Part B

If you were unable to do Part A you should do the following:

- Review the Steps to Follow in Part A to understand how the experiment was done.
- See your learning facilitator for diagrams showing what happens to a bimetallic strip when it is heated in a flame and when it is cooled under cold running water.
- Answer questions 1 to 3 under Part A.

Check your answers with your learning facilitator.

Activity 5: Heating and Cooling Liquids

Remember what happened to the uncalibrated thermometer that you used in the last section. When you placed it in hot water the liquid moved up the tube. As the liquid was heated, it expanded and filled more of the tube. As you cooled the thermometer, the liquid contracted. It took up less space and moved down the tube.

Like gases and solids, liquids expand when heated and contract when cooled. And like gases and solids, liquids can be used to measure temperature in a scale that is calibrated according to how much the substance contracts and expands.

Like metals, liquids do not all expand at the same rate. This activity will show you how this can be demonstrated.

Do either Part A or Part B.

Part A involves doing an experiment to compare how much three different liquids expand when heated.

Part B involves interpreting observations already made regarding the expansion of liquids when heated and then answering the questions for Part A.

Part A

Caution

This activity is to be done under the supervision of the learning facilitator.

Materials You Need

- water
- cooking oil
- glycerine, glycerol, or anti-freeze
- hot plate (or stove)
- three large test tubes
- three one-holed stoppers, each with a long piece of clear plastic tubing inserted
- 500 mL beaker
- stirring rod
- support stand and clamps (optional)
- masking tape

7 Science Directions

Steps to Follow

Note: The instructions for Part A are adapted from the information on page 203 of *Science Directions 7*.

Step 1: Set up the equipment as shown in the diagram on page 203 of the textbook. The liquids in the test tubes should all be at room temperature and the water in the beaker should be drawn from the cold water tap. Adjust the liquids so that they all rise to about the same level in the tubing, just above the stoppers. Mark these levels (the starting positions) with pieces of masking tape.

Step 2: Turn on the hot plate or use a stove set at a low-medium setting. Observe the liquids in the tubing. (If a stove is used, use the next-to-lowest setting or other setting suggested by your learning facilitator.) Carefully stir the water in the beaker.

Caution

Do not let the water in the beaker boil. If one of the liquids comes near the top of the tube, turn off the heat.

Step 3: Turn off the heat after 10 minutes (or sooner if the water starts to boil).

Step 4: In the following observations section, describe what has happened to the level of each liquid. Use measurements in your description of what you observe.

Observations

Steps to Follow (continued)

Step 5: Allow all materials to cool to room temperature before taking them apart. Ask your learning facilitator for advice about what to do with the leftover liquids.

Questions to Answer

1. a. Do liquids expand when they are heated?

_____

b. How do you know?

_____

_____

2. a. Do all liquids expand the same amount when they are heated?

_____

b. How do you know?

_____

_____

Most liquid thermometers have either mercury or coloured alcohol in them. The uncalibrated thermometer you used was likely filled with coloured alcohol, but it may have been filled with a special non-toxic oil. Liquid thermometers are not accurate when the temperature approaches the boiling or freezing point of the liquid inside the thermometer.

Use the information from the following chart to answer questions 3 and 4.

Boiling and Freezing Points of Three Liquids

Substance	Boiling Point (°C)	Freezing Point (°C)
mercury	357	– 40
alcohol	78	– 130
water	100	0

3. a. Which liquid would be best suited for a liquid thermometer used for measuring very cold temperatures?

_____

b. Why?

_____

_____

4. a. Which liquid would be best in a thermometer used to measure the boiling point of water accurately?

_____

b. Why?

_____

_____

Check your answers with your learning facilitator.

Part B

If you were unable to do Part A you should do the following:

- Review the Steps to Follow in Part A to understand how the experiment was done.
- See your learning facilitator for the observations that should have been obtained by those students who were able to do the experiment.
- Answer questions 1 to 4 under Part A.

Check your answers with your learning facilitator.

Activity 6: Specialized Thermometers

Think about all the ways temperature measurement is important in your home. Can you also think of ways it might be important in industry and health care?

Solids, liquids, and gases all expand when heated and contract when cooled, and any one of these might be used in a thermometer. The choice depends on the application or the purpose for which the thermometer will be used.

Do either Part A or Part B.

Part A involves comparing three thermometers. You must have access to at least one solid thermometer and one liquid thermometer. You may ask your learning facilitator for help in obtaining three different types of thermometers.

Part B involves looking at diagrams of special thermometers used for special purposes, reading about them, and answering some questions regarding the different thermometers.

Part A: Comparing Thermometers

Note: You do not need to complete Part A if you wish to do Part B.

For Part A you need three different thermometers (at least one solid and one liquid thermometer). Give each thermometer a number.

1. Observe each thermometer carefully and fill in the following table.

Characteristic of Thermometer	Thermometer 1	Thermometer 2	Thermometer 3
length (cm)			
width (cm)			
lowest temperature			
type of degrees			
substance that expands (solid, liquid, or gas)			
thermometer's use			
advantages			
disadvantages			

2. For each kind of thermometer, explain why you think the solid or liquid that is used in the thermometer was chosen. In what ways is the material suitable?

   a. Thermometer 1:

   _____

   _____

   _____

   b. Thermometer 2:

   _____

   _____

   _____

   c. Thermometer 3:

   _____

   _____

   _____

Check your answers with your learning facilitator.

Part B: Special Thermometers for Special Purposes

Note: You do not need to complete Part B if you have already done Part A.

Laboratory and outdoor thermometers change quickly with any variation in temperature. But in some situations you do not want the reading to change; for example, when a doctor or nurse takes a patient's temperature, they need the reading to stay at the same level long enough to record the patient's temperature after the thermometer has been taken from the patient. A **clinical thermometer** was developed for this purpose.

Clinical thermometer: a thermometer used to measure body temperature

Turn to page 214 of *Science Directions 7* and read about the clinical thermometer. Answer questions 3 and 4 which follow.

3. Why does a clinical thermometer have a scale that only measures from 35°C to 42°C?

4. Why does a clinical thermometer have a constriction?

Return to page 214 of *Science Directions 7* and examine the photograph near the bottom of the page. The photograph shows a liquid crystal thermometer being used to measure a young child's body temperature. Mood rings are another example of a liquid crystal thermometer.

5. Liquid crystal thermometers are sometimes used in place of a liquid thermometer. Why would this be considered a good idea?

6. What is a disadvantage of a liquid crystal thermometer as compared to a clinical thermometer?

Now read the information on page 215 of *Science Directions 7* regarding thermostats.

Thermostat: a device that measures the temperature in a room or an appliance and turns the furnace or appliance on or off to keep the temperature at a desired point

A **thermostat** measures the temperature in an appliance or in a house. The furnace thermostat that is shown on page 215 is a common type found in many homes. If you have the permission and help of an adult, you might want to carefully remove the cover of the furnace thermostat and see what an actual thermostat that controls the furnace looks like. This type of thermostat consists of a bimetallic coil attached to a glass capsule. The glass capsule contains two contacts and a small amount of mercury. With a temperature change, the coil either winds or unwinds changing the tilt of the glass capsule and causing the mercury to move. When the mercury touches both contacts, an electric current flows and the furnace turns on. When the mercury slides away from the contacts, the furnace turns off.

7. Name several appliances that you think would be controlled by thermostats?

_____

_____

_____

8. How can thermostats be used to conserve energy?

_____

_____

_____

As you are probably aware by now, not all thermometers use the principle of expansion and contraction for measuring temperature. You have already learned how a liquid crystal thermometer works. Now read pages 216 and 217 of *Science Directions 7* to see how electricity and light can be used for measuring temperature.

Thermocouple: a device that uses electricity to measure temperature

9. Describe three examples where it would be good to use a **thermocouple**. (Think of situations where you might want to measure the temperature but where it might not be safe to do so using a regular thermometer.)

   - _____
     _____
   - _____
     _____
   - _____
     _____

10. What is an optical pyrometer?

    _____
    _____
    _____

11. What is one advantage of an optical pyrometer over that of a thermocouple?

    _____
    _____
    _____

Check your answers with your learning facilitator.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Temperature can be estimated by observing changes in matter. Thermometers are more accurate than your senses because the changes are compared to a scale that has been calibrated.

Calibration allows you to report temperatures using numbers. If you use a scale that other people are also using, you can clearly communicate what you mean when reporting temperatures.

Thermometers can be made using solids, liquids, or gases.

Look at the following word list. If you do not know what a word means, look back through this section to find out how the word is used.

Word List

accurate	Galileo
air	gas
alcohol	hardness
bends	liquid
bimetallic strip	shape
calibrate	solid
Celsius	states
clinical thermometer	strip
compressed	temperature
contract	thermocouple
degrees	thermometer
expand	thermostat
flow	volume

Crossword Puzzle

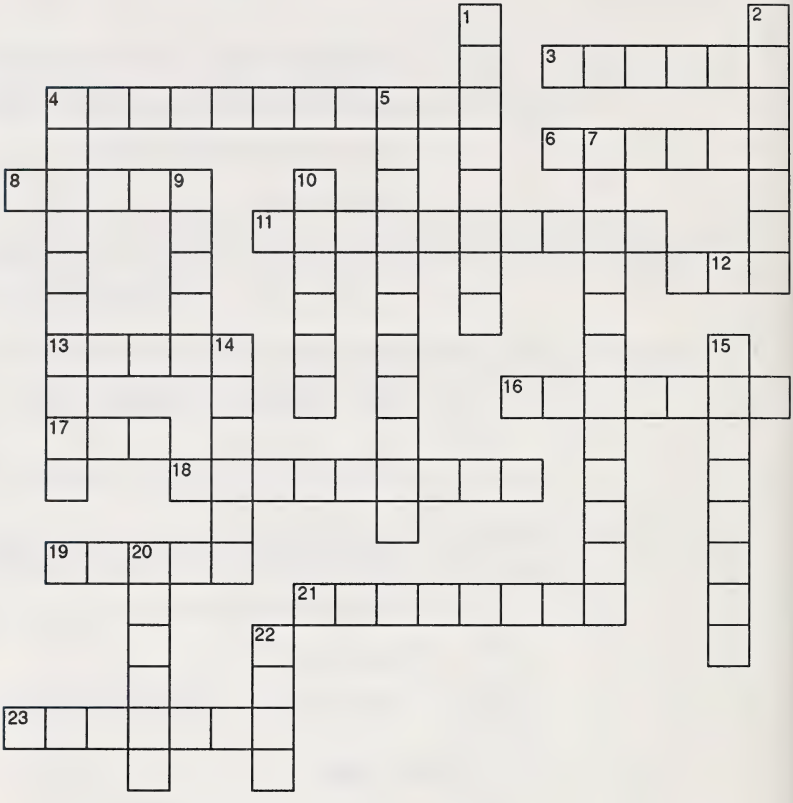
Use the word list to complete the crossword puzzle. A few extra words have been added, so think carefully before you pick which word to use.

Across Clues

3. The amount of space that something takes up is called _____.
4. A device that is calibrated in units called degrees is a _____.
6. Matter can exist in three different _____.
8. A bimetallic strip _____ when heated or cooled.
11. Gases can be _____, but liquids and solids cannot.
12. a state of matter that can change shape and volume
13. A solid is the only state of matter that keeps its _____.
16. This liquid is coloured before it is used in a thermometer.
17. This is what Galileo used in his first thermometer.
18. You need two fixed points to _____ a thermometer.
19. a state of matter that keeps its shape and volume
21. Thermometers are more _____ than your senses to measure temperature.
23. This person made the first thermometer.

Down Clues

1. A change in this could indicate a change in temperature.
2. a temperature scale
4. This device will turn a furnace on or off to control the temperature.
5. This is a measure of how hot or cold something is.
7. a thermometer that uses electricity to measure temperature
9. A bimetallic _____ can be used as a solid thermometer.
10. A change in this could indicate a change in temperature.
14. All three states of matter _____ when heated.
15. All three states of matter _____ when cooled..
20. a state of matter that changes shape but keeps the same volume
22. Liquids and gases _____, but solids do not.



Check your answers with your learning facilitator.

Enrichment

In this activity you will make an air thermometer.

Materials You Need

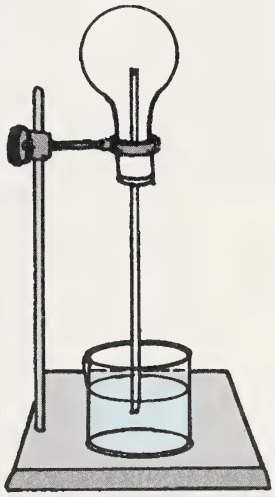
- round-bottomed flask
- 30 cm of transparent rigid plastic tube
- one-holed stopper
- large beaker or container
- coloured water (at room temperature)
- support stand
- clamp
- masking tape

Steps to Follow

Step 1: Insert the rigid plastic tube into the one-holed stopper; then place the stopper into the mouth of the flask.

Step 2: Half fill the beaker with coloured water.

Step 3: Use the stand and clamp to support the flask upside down with the end of the plastic tube in the beaker of water. See the diagram on the right.



Step 4: Place both of your hands around the flask to warm the air inside. Air should bubble out of the tube into the beaker of coloured water.

Step 5: Remove your hands after several bubbles of air have left the tube.

Step 6: As the air in the flask cools, the coloured water should start to rise up the tube. Reheat the flask, if necessary, so that the water level rises halfway up the tube after the flask has cooled. This may take several attempts.

Step 7: Mark the level of the water with a piece of masking tape.

Step 8: Carefully move your air thermometer to warmer and cooler places. Use masking tape to mark the level of the coloured water for each location.

Questions to Answer

1. In which direction did the coloured water move when you took the air thermometer to a warm location?

2. Explain why it moved in that direction.

3. In which direction did the coloured water move when you took the air thermometer to a cool location?

4. Explain why it moved in that direction.

5. Explain how you could make a scale for your thermometer.

6. What is one advantage of using your air thermometer?

7. What is one disadvantage of using your air thermometer?

Check your answers with your learning facilitator.

Conclusion

In this section you have learned that changes in an object are important clues about whether the object is hot or cold. One important change is that all states of matter expand when heated and contract when cooled. You can use this change to make a thermometer using a gas, a liquid, or a solid.

Specialized thermometers have been made to measure very high temperatures, very low temperatures, and temperatures in hard to reach locations.

Knowing that something is hot or cold is only the first step. Scientists have used temperature measurements to develop an explanation of what heat is. You will learn about this theory in the next section.

Assignment Booklet

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 2.

Section

3

Heat and Temperature

WESTFILE INC.

So far in this module you have learned a great deal about temperature and how it can be measured. You can say that the temperature of an object is hot, cold, or warm; or you can be more precise and state its temperature in degrees Celsius. Either way, you are describing the conditions of one object at one particular time when you refer to its temperature.

Is temperature the same as heat? You would probably predict that if you add heat to something, its temperature would go up. But there are times when adding heat may not increase the temperature. Does a cup of water at 20°C have the same amount of heat as a bathtub full of water at 20°C?

In this section you will learn the difference between heat and temperature. You will start to think of heat as moving from one object to another object. For example, if you put your hand in hot water, some heat transfers from the water to your hand. But sometimes you do not want heat transfer to occur. In the photograph the firefighters are wearing protective clothing to prevent heat from transferring to their bodies. Heat is a form of energy.

You will learn about the theory that scientists have developed to explain heat. You will start to understand that while heat and temperature are related, they are not the same thing.

Activity 1: Heat and the Amount of Matter

Heat: the energy transferred from a hot substance to a colder one

If you are cold and you have a choice of a bathtub filled with water at 10°C and one filled with water at 30°C, you would choose the latter. It has more **heat**. But does heat only depend on temperature? If it does, then heat and temperature would be basically the same. The activities in this section will give you evidence that heat and temperature are not the same. The problems you will be working on are the same ones that scientists have tried to solve in the past.

In this activity and in other activities in this section, you will be using a hot plate (or stove) as a source of heat. You will set the hot plate to a medium setting and let it warm up. Once it is warm, it gives off heat at a fairly constant rate so long as the setting is not changed. This information is important for Activity 1.

Caution

This activity is to be done under the supervision of the learning facilitator.

In this activity you will heat a small amount of water and measure the change in temperature. Then you will add the same amount of heat to a larger amount of water and measure its temperature change.

If heat and temperature are the same thing, adding the same amount of heat to two samples of water should cause the same change in temperature.

However, if heat and temperature are **not** the same, then adding the same amount of heat to two samples of water could cause a different change in temperature.

You will add the same amount of heat to the water samples by heating each of them for the same amount of time.

Problem

What happens to the temperature if the same amount of heat is added to different amounts of water?

Materials You Need

- water
- thermometer, with a range to 100°C
- graduated cylinder or measuring cup
- hot plate or stove
- beaker, heat resistant cup, or small pan
- support stand (optional)
- two clamps (optional)
- timer

Steps to Follow

Note:
- If you are using the optional support stand and clamps, your setup may resemble the diagram shown on page 224 of *Science Directions 7*.
- If you are not using the support stand, be careful that when you are measuring the temperature of the water, the bulb of the thermometer does not touch the bottom of the beaker.

Step 1: Turn the hot plate on to a medium temperature to let it warm up. (If a stove is used, put it at the next-to-lowest setting or other setting suggested by your learning facilitator.)

Step 2: Using the graduated cylinder, measure 100 mL of water.

Step 3: Pour the water into the beaker.

Step 4: Measure the temperature of the water in the beaker. Record this in the column *100 mL of Water* in the observation chart. Put this first reading beside 0 minutes.

Step 5: Place the beaker of water on the hot plate.

Step 6: Measure the temperature every minute. Record your results in the observation chart. Keep on recording the temperature for 5 minutes.

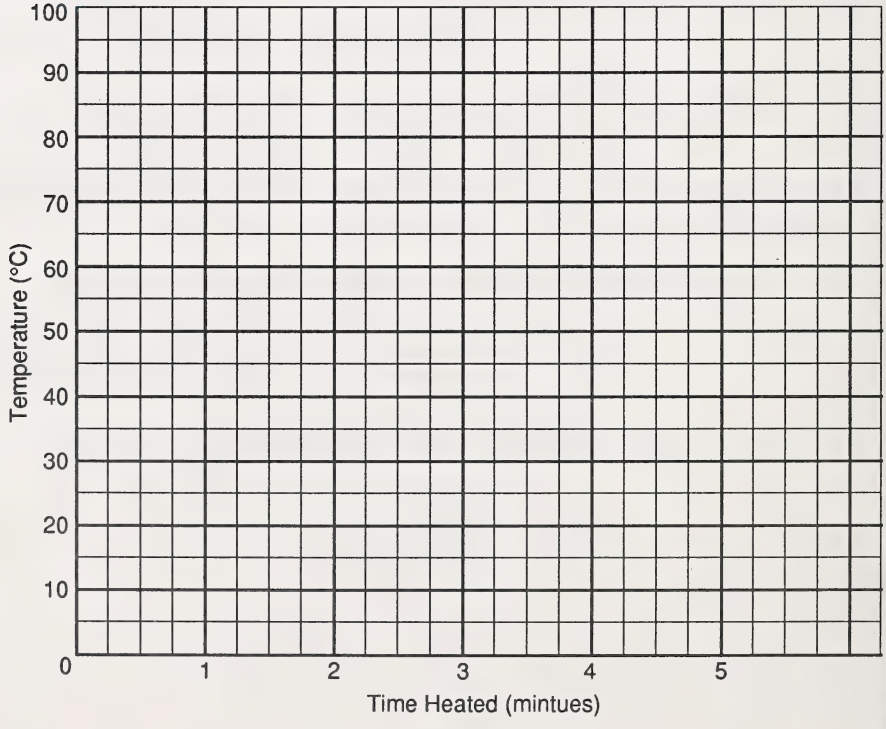
Step 7: Repeat steps 3 to 6 using 200 mL of water.

Observations

Time (Minutes)	Temperature (°C) 100 mL of Water	Temperature (°C) 200 mL of Water
0		
1		
2		
3		
4		
5		

Now draw a line graph showing the temperature at each time interval for the different amounts of water. Use different colours to show your results for each amount of water.

Graph One: Temperature Change and Heating Time for Water



Questions to Answer

1. a. Was about the same amount of heat added to each sample?

   _____

   b. How do you know?

   _____

   _____

2. Which amount of water had the higher temperature at the end of 5 minutes?

   _____

3. Draw a line on the graph to predict what the temperature readings would be if you had used 300 mL of water. Why did you draw it where you did?

   _____

   _____

   _____

4. a. Do your observations support the idea that heat and temperature are the same?

   _____

   b. Give a reason for your answer.

   _____

   _____

5. Imagine that you heated 500 mL of water from 20°C to 50°C. Next you wanted to heat 800 mL of water from 20°C to 50°C. Circle the correct statement.

   a. Both samples contain the same amount of energy at 50°C.
   b. The 500 mL of water contains more energy at 50°C.
   c. The 800 mL of water contains more energy at 50°C.

6. Give a reason for your answer to question 5.

_____

_____

Check your answers with your learning facilitator.

Activity 2: Heat and Type of Matter

In Activity 1 you found that adding the same amount of heat to different amounts of water resulted in different temperature changes. This is evidence that there is something different about heat and temperature. The same amount of heat was added to both water samples, but the temperatures did not change the same amount. It seems that heat depends on temperature but it also depends on something else – the amount of the substance.

Does heat depend on anything else? Scientists asked this question. Think about this question during this activity.

Caution

This activity is to be done under the supervision of the learning facilitator.

Problem

Do different types of matter show the same changes in temperature when the same amount of heat is added?

Materials You Need

- hot plate or stove
- beaker, heat resistant cup, or small pan
- thermometer with a range to 100°C
- graduated cylinder or measuring cup
- water
- cooking oil
- glycerine (glycerol) or anti-freeze
- support stand (optional)
- two clamps (optional)
- timer

Steps to Follow

Step 1: Turn on the hot plate to a medium setting to warm it up. (If a stove is used, set it on the next-to-lowest setting or another setting suggested by your learning facilitator.)

Step 2: Measure 100 mL of water in the graduated cylinder (or measure 100 mL using the markings on the side of the beaker or measuring cup).

Step 3: Pour the water into the beaker and measure the temperature.

Step 4: Record the temperature in the observations chart under the heading *Water* and beside *0 minutes*.

Step 5: Heat the water on the hot plate or stove for 5 minutes, recording the temperature every minute.

Step 6: Cool, clean, and dry the beaker or pan before using it for the next liquid. Wipe the thermometer clean also.

Step 7: Repeat steps 1 to 6 using cooking oil; then repeat steps 1 to 6 using glycerine.

Note: All liquids should have approximately the same starting temperatures in step 3.

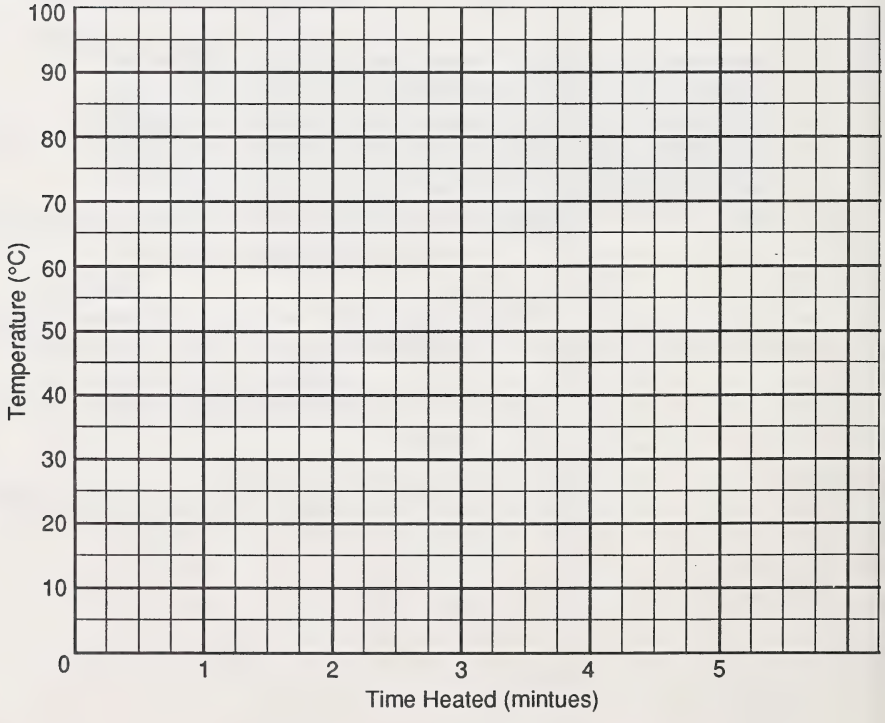
Step 8: Make a line graph of your results using a different colour for each liquid.

Observations

Time (Minutes)	Temperature of Liquids (°C)		
	Water	Cooking Oil	Glycerine
0			
1			
2			
3			
4			
5			

Now draw a line graph showing the temperature at each time interval for the water. Use different colours to draw lines for cooking oil and for glycerine.

Graph Two: Temperature Change and Heating Time for Three Different Liquids



Questions to Answer

1. a. Was the same amount of heat added to each sample?

   _____

   b. How do you know?

   _____

2. Which type of liquid showed the greatest increase in temperature?

   _____

3. Which type of liquid showed the smallest increase in temperature?

   _____

4. a. Do your observations support the idea that heat and temperature are the same?

   _____

   b. Give a reason for your answer.

   _____

   _____

   _____

5. Imagine that you heated 500 mL of water from 20°C to 50°C. Next you wanted to heat 500 mL of cooking oil from 20°C to 50°C. Circle the correct statement.

   a. Both samples contain the same amount of energy at 50°C.
   b. The 500 mL of water contains more energy at 50°C.
   c. The 500 mL of cooking oil contains more energy at 50°C.

6. Give a reason for your answer to question 5.

Check your answers with your learning facilitator.

Activity 3: A Hypothesis to Explain Heat

Your observations in the previous activities have shown that heat and temperature are not the same. Temperature indicates how hot or cold something is. Heat is the energy that is transferred from a hotter substance to a colder substance. The total amount of energy in something seems to depend on

- the temperature of the substance
- the amount of the substance
- the type of substance

A hypothesis is a set of ideas or a model that a scientist puts together to try to explain why an event occurs in the natural world. The scientist tests the hypothesis by making predictions based on the hypothesis and then carrying out experiments to check the predictions. If the predictions are incorrect, the scientist rejects the hypothesis or makes changes to it. If the predictions are correct, the hypothesis gains support. If all the experiments done by many different scientists support the hypothesis, and no experiments have shown it to be false, the hypothesis is accepted as a **theory**. A theory continues to be used to explain things until evidence is found to disprove it.

Theory: a hypothesis that has been supported by experiments done by many scientists

About 200 years ago, a French scientist named Antoine Lavoisier suggested a hypothesis to explain what heat is.

Read the cartoon Great Moments in the History of Heat! on pages 220 and 221 of *Science Directions 7* to learn about Lavoisier's hypothesis.

Lavoisier's hypothesis stated that heat was made of *caloric fluid.* As this fluid flowed from a hot object into a cooler object, the cooler object would heat up. Since heat is considered to be a fluid, when heat is added to an object, the object should gain mass. When heat leaves an object, the object should lose mass. For example, if Lavoisier's hypothesis were true, then water should gain mass during heating and lose mass when changing from water to ice. Do you think Lavoisier's hypothesis was correct?

Part A is optional, but
you must do Part B.

Part A involves designing an experiment to test Lavoisier's hypothesis.

Part B involves reading about an experiment and then answering some questions.

Part A: Designing an Experiment (Optional)

Using Lavoisier's hypothesis, you can predict that as water freezes, it should lose mass. Design an experiment to test this prediction.

Materials You Need

List the materials you would need.

Steps to Follow

Write the steps in the order you would follow them.

Discuss your answers with your learning facilitator.

Part B: Interpreting an Experiment

Note: You must do Part B even if you have already done Part A.

Benjamin Thompson (also known as Count Rumford of Bavaria) was another scientist who investigated heat. Read Water to Ice on page 222 of *Science Directions 7* to find out if his results supported Lavoisier's hypothesis.

1. Why should water lose mass as it turns to ice if Lavoisier's hypothesis is correct?

2. Did Thompson's experiment support Lavoisier's hypothesis?

_____

3. Give a reason for your answer to question 2.

_____

_____

_____

Check your answers with your learning facilitator.

Activity 4: A Theory to Explain Heat and Temperature

You are probably wondering why you were given a hypothesis about heat that has turned out to be incorrect. Lavoisier was a very good scientist. Most of the hypotheses that scientists make are changed or rejected when new evidence is gathered. This is the way science works. Scientists are constantly seeking better explanations.

Since heat flows from warm objects to cooler objects, Lavoisier thought that heat might be a fluid. Experiments based on this idea showed that heat was not a fluid.

Particle theory : the theory that all matter is made up of tiny particles that are always moving

Scientists now use the **particle theory** to explain heat and temperature. This theory is based on a model that suggests that all matter is made up of tiny particles too small to be seen. According to the model, these particles are always moving – that is, they have energy. The more energy they have, the faster they move. For example, both hot and cold water are made up of moving particles. But the particles move faster in hot water than in cold water.

Turn to page 225 of *Science Directions 7* and read Heat and the Particle Theory. Find out why the particle model for matter is a theory.

Energy content: the amount of energy contained in a substance

Now, think about the three variables that affect the total **energy content** in an object – temperature, amount of matter, and type of matter.

The particle theory can explain each one.

Temperature

If you add heat energy to water, each water particle receives some of the energy and will start to move faster. As all of the particles start to move faster, the temperature increases. Temperature is an indicator of how fast the particles are moving.

If you remove heat energy from water, the water particles move slower and the temperature drops.

The particle theory of matter explains temperature as the average speed of the particles.

Amount of Matter

A 100 mL sample of water has half as many water particles as a 200 mL sample of water. So if you add the same amount of heat energy to both samples of water, each water particle in the 100 mL sample would receive more of the energy than each water particle in the 200 mL sample. The heat energy will be divided up into smaller packages if there are more particles to receive the energy.

If you had twenty dimes and gave them to five friends, each friend would receive four dimes. However, if you gave the same twenty dimes to ten friends, each friend would only receive two dimes. The larger the group, the less each individual receives. Similarly, for the example of heating water, the larger the sample of water (more water particles), the less heat each individual water particle receives.

A higher temperature indicates that particles are moving faster. Particles move faster when they receive energy. Each water particle in the 100 mL sample receives more of the heat energy and will speed up more. The particles in the 100 mL water sample will be moving faster than the water particles in the 200 mL sample after receiving the same amount of heat energy. This means that the water particles in the 100 mL sample will be moving faster, so the temperature will increase more.

This is exactly what you found out in Activity 1. Look back at *Graph One: Temperature Change and Heating Time for Water*. The particle theory of matter explains why the line for 100 mL of water changed temperature faster than the line for 200 mL of water. The particle theory of matter is a good explanation for temperature changes of different amounts of matter when they are given the same amount of heat energy.

Type of Matter

The particles of cooking oil are different than the particles of water. If you add the same amount of heat energy to cooking oil and water, the cooking oil particles speed up more than the water particles.

If the cooking oil particles move faster than water particles when given the same amount of heat, the temperature of the cooking oil will change more than the temperature of the water.

This is what you observed in Activity 2. Look back at *Graph Two: Temperature Change and Heating Time for Glycerine*. Using the particle theory of matter, you can find out how the speed of different types of particles change by comparing them to water particles. The particle theory of matter is a good explanation for why different types of matter respond differently to the same amount of heat.

1. Describe the particle theory.

_____

_____

_____

_____

2. Why is the particle theory called a theory instead of a hypothesis?

_____

_____

_____

_____

3. List three variables that are taken into account when discussing the total energy content in a sample of matter.

_____

_____

_____

Now turn to page 231 of *Science Directions 7* and read Temperature, Total Energy, and Heat: A Summary. Study the three situations shown to be sure you understand how temperature, total energy, and heat compare with each other. Then use the particle theory to answer questions 4 to 7.

4. A kettle and a cup both contain water at 50°C. Use the particle theory to explain why the temperature is the same in both samples of water, even though the kettle has the greater amount of water.

5. Two cups contain the same amount of water. In one cup the water is at 20°C, and in the other it is at 80°C. According to the particle theory, why is the temperature higher in the cup at 80°C?

6. When the two samples of water are at 50°C, why is the total energy greater in the sample of water in the kettle than in the sample of water in the cup?

7. When two equal amounts of water at different temperatures are mixed, describe the heat transfer that occurs.

The third illustration shows two unequal amounts of water at different temperatures. The temperature in the cup is higher because the average speed of the particles is faster. The total energy cannot be compared at this stage as the calculations needed would not make sense to you right now. If the two samples are mixed, heat transfers from the warmer sample to the cooler one. Heat always moves from matter at a high temperature to matter at a lower temperature.

In the next few activities you will do experiments to test the ideas presented in Activity 4. After completing Activities 5, 6, and 7 you should have a better understanding of how heat and temperature are different.

Check your answers with your learning facilitator.

Activity 5: Equal Amounts of Water to Compare Heat and Temperature

The particle theory of matter predicts that heat should move from something at a high temperature to something at a lower temperature. When heat moves **from** some matter, the energy of that matter decreases. The particles start to move more slowly and the temperature goes down. When heat moves **to** some matter, the energy of that matter increases. The particles will start to move faster and the temperature increases. In situations like this, you can usually tell if heat has been added or taken away by measuring the temperature.

In this activity you will try to estimate the final temperature after mixing two samples of water.

Materials You Need

- two cups or beakers
- uncalibrated thermometer
- 100 mL graduated cylinder or measuring cup
- cold water
- hot water from tap
- masking tape
- stirring rod, stir stick, or spoon

Steps to Follow

Note: Activities 5 and 6 are adapted from the information on page 219 of *Science Directions 7*. You might find it helpful to refer to the information and diagrams on that page before doing the following steps.

Step 1: Put a strip of masking tape on the uncalibrated thermometer so that you can mark temperatures on it.

Step 2: Using the graduated cylinder, measure 50 mL of hot tap water and pour it into a glass or cup.

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Step 3: Put the uncalibrated thermometer into the cup and mark the temperature on the thermometer with a marker.

Step 4: Measure 50 mL of cold tap water and pour it into a second cup.

Step 5: Put the uncalibrated thermometer into the second cup and mark the temperature on the thermometer with a marker.

Step 6: Add the hot water to the cold water. Stir the mixture using the stirring rod. (To prevent breakage, do not stir while the thermometer is in the water.)

Step 7: Mark the temperature of the mixture on the thermometer.

Questions to Answer

1. The hot water contained (circle one)

   a. many more particles than the cold water
   b. about the same number of particles as the cold water
   c. many less particles than the cold water

2. Was the final temperature of the mixture closer to the temperature of the hot water, the cold water, or was it about halfway between the two temperatures?

   _____

   _____

3. Explain your observation using the particle theory of matter. What happens to the particles of hot water and cold water when they are mixed?

   _____

   _____

   _____

4. a. If you mixed 100 mL of water at 20°C with 100 mL of water at 60°C, what would the final temperature be?

      _____

      _____

b. Give a reason for your prediction.

_____

_____

_____

Check your answers with your learning facilitator.

Activity 6: Different Amounts of Water

Materials You Need

- two cups or beakers
- uncalibrated thermometer
- 100 mL graduated cylinder or measuring cup
- cold water
- hot water from tap
- masking tape
- stirring rod, stir stick, or spoon

Steps to Follow

Step 1: Put a new strip of masking tape on the uncalibrated thermometer so that you can mark temperatures on it.

Step 2: Using the graduated cylinder or measuring cup, measure 100 mL of hot tap water and pour it into the cup or beaker.

Step 3: Put the uncalibrated thermometer into the cup and mark the temperature on the thermometer with a marker.

Step 4: Measure 50 mL of cold tap water and pour it into a second cup.

Step 5: Put the uncalibrated thermometer into the second cup and mark the temperature on the thermometer with a marker.

Step 6: Add the hot water to the cold water. Stir the mixture using the stirring rod. (To prevent breakage, do not stir while the thermometer is in the water.)

Step 7: Mark the temperature of the mixture on the thermometer.

Questions to Answer

1. The hot water contained (circle one)

   a. many more particles than the cold water
   b. about the same number of particles as the cold water
   c. many less particles than the cold water

2. Was the final temperature of the mixture closer to the temperature of the hot water, the cold water, or was it about halfway between the two temperatures?

   _____

   _____

3. a. If you mixed 100 mL of water at 20°C with 200 mL of water at 60°C, what would the final temperature be?

      _____

      _____

   b. Give a reason for your prediction.

      _____

      _____

      _____

Check your answers with your learning facilitator.

Activity 7: Equal Amounts of Different Substances

Materials You Need

- two cups or beakers
- uncalibrated thermometer
- 100 mL graduated cylinder or measuring cup
- cold water
- hot water from tap
- cooking oil
- masking tape
- stirring rod, stir stick, or spoon

Steps to Follow

Step 1: Put a new strip of masking tape on the uncalibrated thermometer so that you can mark temperatures on it.

Step 2: Using the graduated cylinder, measure 100 mL of hot tap water and pour it into a glass or cup.

Step 3: Put the uncalibrated thermometer into the cup and mark the temperature on the thermometer with a marker.

Step 4: Measure 100 mL of cold cooking oil and pour it into a second cup.

Step 5: Put the uncalibrated thermometer into the second cup and mark the temperature on the thermometer with a marker.

Step 6: Add the hot water to the cold cooking oil. Stir the mixture using the stirring rod. (To prevent breakage, do not stir while the thermometer is in the water.)

Step 7: Mark the temperature of the mixture on the thermometer.

Questions to Answer

1. Was the final temperature of the mixture closer to the temperature of the hot water, the cold cooking oil, or was it about halfway between the two temperatures?

2. a. If you mixed 100 mL of cooking oil at 20°C with 100 mL of water at 60°C, approximately what would the final temperature be?

_____

b. Give a reason for your prediction.

_____

_____

_____

Check your answers with your learning facilitator.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

In Activities 4, 5, and 6, you observed that the final temperature of a mixture is somewhere between the starting temperatures of the substances. You have learned that heat is a form of energy. Because heat is energy, it can transfer from one object to another. In your mixtures, heat flowed or transferred from the hot substance to the cooler substance. Heat will always flow from an object at a high temperature to an object at a lower temperature.

Imagine getting into bed on a cold winter night. The sheets feel very cold against your skin. After a while, the sheets feel warm. Your body temperature is 37°C and the sheets were at room temperature (20°C). Heat was transferred from your body to the sheets to warm them up. The final temperature will not be halfway between these two temperatures – there is more of you than there is of the sheets!

In each of the following described situations, state in which direction the heat will flow.

1. Water at 30°C is poured onto your back (37°C).

_____

_____

2. 500 mL of water at 25°C is mixed with 10 mL of water at 90°C.

_____

_____

3. A spoon at 25°C is placed into a cup of water at 5°C.

_____

_____

You learned about the particle theory of matter. Temperature is the average speed of the tiny moving particles that make up matter. The total energy content of something depends on

- the type of particles (type of substance)
- the speed of particles (temperature)
- the number of particles (amount of the substance)

Use the following words to fill in the blanks for questions 4 to 10. You may use a word as many times as needed. You will not use all the words.

Word List

colder	heat	same
different	hotter	slower
faster	more	stationary
fewer	moving particles	temperature

4. Matter is made up of small _____.

5. Heat moves from _____ substances to _____ substances.

6. Particles of matter are always _____.

7. 100 mL of water has _____ particles than 25 mL of water.

8. Water at 35°C has _____ particles than water at 25°C.

9. 100 mL of oil at 35°C has _____ total energy than 50 mL of oil at 35°C.

10. 35 mL of water at 15°C has the same _____ as 200 mL of cooking oil at 15°C.

For questions 11 and 12 you may wish to refer to *Graph One: Temperature Change and Heating Time for Water* in Activity 1 and *Graph Two: Temperature Change and Heating Time for Three Different Liquids* in Activity 2. Use the particle theory of matter to explain the questions.

11. Why does the temperature of 200 mL of water change more slowly than the temperature of 100 mL of water when heated?

_____

_____

_____

_____

12. (Optional) Why does cooking oil heat up faster than water?

_____

_____

_____

_____

Check your answers with your learning facilitator.

Enrichment

Do either Part A or Part B, or
do both Part A and Part B.

Part A involves doing an experiment to determine what happens to the temperature of ice during melting.

Part B involves using your knowledge of the particle theory to answer questions.

You may choose to do only Part A or Part B, but you may do both Part A and Part B if you wish.

Part A: Temperature Change During Melting

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This enrichment activity is adapted from the information on page 223 of *Science Directions 7*. You might find it helpful to refer to the textbook if you want additional information.

Materials You Need

- thermometer
- beaker or cup
- timer
- crushed ice
- freezer

Steps to Follow

Step 1: If you do not have a source of crushed ice, crush some ice cubes by wrapping them in a towel and striking them against some solid object. Place the crushed ice into a freezer until needed.

Step 2: Fill the cup or beaker with crushed ice and measure the temperature as quickly as you can.

Step 3: Measure the temperature every minute for 12 minutes or until the ice has completely **melted**. Under the heading *Observations*, construct a chart to record all measurements. (Note: The very first observation you made will be for 0 minutes, the next for 1 minute, 2 minutes, and so on.)

Melted: the change of state from solid to liquid

Observations

Questions to Answer

1. What change of state occurs in this activity?

2. This change of state needs heat energy. Where did the heat energy come from?

3. What happens to the temperature during this change of state?

4. Why is the melting point of ice a good fixed point to use when calibrating a thermometer?

Check your answers with your learning facilitator.

Part B: Predicting Based on Theory

Heat always flows from a substance with a high temperature to a substance with a lower temperature. Your body temperature is 37°C. The room you are in is most likely close to 20°C. A metal spoon in the room will be at the same temperature as the room. If you pick up the spoon, heat will flow from your body into the spoon. That is why it will feel cool when you touch it. Heat will not flow easily through wood. Since less heat will flow from your body through wood, a wooden spoon at room temperature will not feel as cold as a metal spoon. But heat will always move from hot objects to cold objects.

When you mix liquids, the final temperature will be somewhere between the temperatures of the two liquids. In predicting final temperatures of mixtures, you should remember the following points:

- Heat always moves from substances with high temperatures to substances with lower temperatures.
- The total amount of energy that can be transferred depends on the amount of matter, the type of matter, and the temperature difference.

When you experimented in this section, you found out that cooking oil particles speed up (change temperature) more than water particles for the same amount of heat. This means that cooking oil will change temperature more than water when cooking oil is mixed with water.

Suppose you have two cups of water. Cup 1 contains 100 mL of water at 10°C. Cup 2 contains 100 mL of water at 30°C. Use this information to answer questions 5 to 8.

5. Which is at the higher temperature?

_____

6. a. Which cup contains the most energy?

_____

b. Give a reason for your answer.

_____

_____

_____

7. a. From which water would the heat move if the two were mixed?

_____

b. Give a reason for your answer.

_____

_____

_____

8. a. If the two were mixed, the final temperature would be (circle one)

i. closer to 30°C than to 10°C
ii. closer to 10°C than to 30°C
iii. about halfway between 30°C and 10°C

b. Give a reason for your answer.

_____

_____

_____

Suppose you have two more cups of water. Cup 3 contains 300 mL of water at 10°C. Cup 4 contains 100 mL of water at 10°C. Use this information to answer questions 9 to 12.

9. Which is at the higher temperature?

_____

10. a. Which cup contains the most energy?

_____

b. Give a reason for your answer.

_____

_____

_____

11. a. From which water would the heat move if the two were mixed?

_____

b. Give a reason for your answer.

_____

_____

_____

12. Predict the final temperature if you were to mix the two.

_____

Suppose you have another two cups. Cup 5 contains 100 mL of cooking oil at 10°C. Cup 6 contains 100 mL of water at 30°C. Use this information to answer questions 13 to 16.

13. Which is at the higher temperature?

_____

14. a. Which cup contains the most energy?

_____

b. Give a reason for your answer.

_____

_____

_____

15. a. From which substance would the heat move if the two were mixed?

_____

b. Give a reason for your answer.

_____

_____

16. If the two were mixed, the final temperature would be (circle one)

a. closer to 30°C than to 10°C
b. closer to 10°C than to 30°C
c. about halfway between 30°C and 10°C

Check your answers with your learning facilitator.

Conclusion

In this section you learned that temperature and heat are different things. You also learned about the particle theory of matter which is used to explain the difference between heat and temperature.

Temperature is a measurement of the average energy of a substance or how hot or cold it is. According to the particle theory of matter, the particles of a substance move faster if the temperature is high.

The total energy content of a substance depends on three things:

- temperature
- type of matter
- amount of matter

Heat is the energy transferred from a hot substance to a colder one. Heat always moves from a substance with a high temperature to a substance with a lower temperature.

Assignment Booklet

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 3.

Section

4

Sources of Heat

You have probably helped prepare food on a barbecue grill. You have warmed your hands by rubbing them together. You know how hot a light bulb is after is has been turned on for a while. Possibly you have been swimming in the warm water at the Miette Hot Springs or the Banff Hot Springs pool. Where did the heat come from for each of these activities? What are the advantages and disadvantages of different sources of heat? Which fuels contain the most energy? You should be able to answer these questions after working through this section.

Activity 1: Measuring Heat

When you measure a distance, you use the unit millimetre (mm), centimetre (cm), metre (m), or kilometre (km). When you measured force in Module 2, you used the unit newton (N). In this module you made a temperature scale marked in units called degrees Celsius (°C). You also need a unit when referring to amounts of heat energy.

Joule: unit for measuring energy; the amount of energy that would be required to raise a 100 g of mass 1 m

Heat can be measured in a unit called a **joule**. The symbol for joule is J. A capital J is used since the joule is named after James Joule, an English scientist who studied heat and energy. One joule is a very small amount of energy. Often it is more useful to measure energy in kilojoules (1 kJ = 1000 J), or megajoules (1 MJ = 1 000 000 J).

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To get an idea of the size of these units of energy, read the information on page 235 of *Science Directions 7*.

Remember, whenever you see the unit *joule* following a measurement, you know that some form of energy is being measured.

Chemical Energy

Chemical energy: the energy stored in food and fuel

Food and fuels have energy stored in them. This kind of energy is called **chemical energy**. Heat is released from food and fuels through the chemical process of burning. To release the heat in your body, food is digested instead of being burned. The digestive process releases the heat gradually so that there is no damage to your body.

Your body uses the food you eat to produce the energy you need to swim, hike, run, lift your arm, wriggle your toe – every single action you take. The energy stored in food also produces heat to keep your body temperature at about 37°C.

Western and northern Canada are especially well supplied with fuels that can be used to provide heat. There are solid fuels such as wood and coal, liquid fuels such as oil and gasoline, and gaseous fuels such as natural gas and propane.

- How is food similar to fuel such as gasoline?
- Can the energy of a burning fuel be used to heat water?
- What happens to the temperature when you apply more heat to a sample of water?
- How can you measure heat?

Think about these questions. This activity will help you find the answers.

Part A is optional, but
you must do Part B.

Part A involves doing an experiment to compare the energy content of peanuts and walnuts. Although it is optional, it is suggested that you attempt Part A as the results obtained are quite interesting.

Part B involves using information in charts to compare the energy content of different foods and fuels. It must be done by all students.

Part A: Measuring Heat Content of Foods (Optional)

Caution

This activity is to be done under the supervision
of the learning facilitator.

Although your body does not burn food with a fire, the energy stored in food can be turned into heat by your body. However, by burning different foods with a flame, you can compare the amount of energy stored in foods. In Part A, you will compare the energy stored in a peanut with the energy stored in a walnut.

Materials You Need

- a shelled peanut
- a shelled walnut
- pin embedded in cork or eraser
- two empty pop cans
- graduated cylinder or measuring cup
- oven mitt
- thermometer
- matches
- safety glasses
- water
- aluminum foil

Steps to Follow

Step 1: Very carefully place a peanut on the sharp end of a pin that has been embedded in a cork. It may help to turn the peanut back and forth to drill a tiny hole with the pin.

Note: This experiment was adapted from the information on page 236 of *Science Directions 7*. See the diagram under number 3 of the Procedure on page 236 of the textbook to see how to place the peanut on the pin. Then continue with step 2.

Step 2: Measure 100 mL of water at about 20°C into one of the pop cans.

Step 3: Measure the exact temperature of the water. This is the starting temperature. Record this measurement in the chart.

Step 4: Cut a square (15 cm × 15 cm) of aluminum foil. Place the cork and peanut on the aluminum foil.

Step 5: Use the match to light the peanut. You may need to use more than one match to start the peanut burning. Taking care not to burn yourself, hold the burning match so that the tip of the flame is touching the bottom of the peanut.

Step 6: As soon as the peanut is burning without the assistance of the match, hold the can of water so that the tip of the flame from the peanut just touches the bottom of the can.

Step 7: Hold the can of water above the flame until the peanut stops burning.

Step 8: As soon as the peanut stops burning, set the can of water on the aluminum foil.

Caution

The bottom of the can will be very black. Do not touch the bottom of the can with your hands or clothes.

Step 9: Measure the temperature of the water. This is the final temperature of the water. Record this measurement in the chart.

Step 10: Empty the can, let it cool, and then throw it into a garbage pail.

Step 11: Repeat steps 1 to 10 using the shelled walnut. Record the measurements you found when you used the walnut in the chart.

Observations

Type of Nut	Starting Temperature of Water (° C)	Final Temperature of Water (° C)
peanut		
walnut		

Questions to Answer

1. What was done so that the energy in the food could be used to heat water?

_____

_____

_____

_____

2. How is food similar to fuels such as wood or gasoline?

_____

_____

_____

_____

3. What happens to the temperature when you apply more heat to a sample of water?

4. What was the temperature change for the water heated by a peanut?

5. What was the temperature change for the water heated by a walnut?

6. a. Which nut contains the most energy?

   b. Give a reason for your answer.

Check your answers with your learning facilitator.

Part B: Interpreting Heat Content of Foods

Note: You must complete Part B, even if you have already done Part A.

Nutritionists, food scientists, and doctors all want to know the energy content of food. By knowing the energy content of food, they can plan diets for their patients. It is necessary that the measurements of the energy content of food be accurate. They use an instrument called a bomb calorimeter to burn food and measure the temperature increase of water. This instrument does not allow heat to escape and heat the air. There is no waste heat. The same measurements are made several times to make sure the results are accurate.

Scientists collect data on all types of foods so that comparisons can be made. In this way, food scientists, nutritionists, and doctors can better plan diets.

The chart which follows shows a comparison of the energy content of foods. Food energy is measured in units called kilojoules (1000 joules). The chart shows the energy content in joules for each gram of the food. The higher the energy content of the food, the more heat it can produce. For example, each gram of a chocolate milkshake contains 4950 joules of energy. This is expressed as 4950 J/g (joules per gram). A typical chocolate milkshake is 400 grams. To find the total energy content of a milkshake, multiply the energy content of one gram (4950 J/g) by the mass of the milkshake (400 g).

$$4950 \text{ J/g} \times 400 \text{ g} = 1\,980\,000 \text{ J}$$

The total energy content of the milkshake is 1 980 000 J or 1980 kJ. (To change from joules to kilojoules, just divide by 1000, or move the decimal three places to the left.)

By using information in the chart which follows, you can calculate how much energy is contained in a serving of several foods. If you were on a diet to lose weight, you should choose foods lower in energy content. For example, which would contain more energy – a serving of peanut butter or a banana? The peanut butter has more energy for each gram, but a banana is much larger. Use the chart to answer questions 7 to 14.

Food Energy Content

Food	Energy Content (Joules per Gram)	Mass of a Typical Serving (Grams)
chocolate milkshake	4 950	400
fried egg	7 350	46
wiener	3 200	37
peanut butter	24 750	16
banana	3 850	114
apple pie (slice)	10 700	158
chocolate bar	19 600	30

7. Calculate the total energy content of one serving of each food. The first one has been done for you.

chocolate milkshake $4950\ J/g \times 400\ g = 1\ 980\ 000\ J = 1980\ kJ$

fried egg _____

wiener _____

peanut butter _____

banana _____

apple pie (slice) _____

chocolate bar _____

8. List the foods from greatest to least energy content for a serving.

   greatest energy content _____

   _____

   _____

   _____

   _____

   _____

   least energy content _____

9. Which food has the highest energy in one gram?

   _____

10. Which food has the least energy in one gram?

    _____

11. Which food has the highest energy in one serving?

    _____

12. Which food has the least energy in one serving?

    _____

13. a. If you had not eaten for a long time and needed energy, which serving of food would give you the most energy?

    _____

    b. Why?

    _____

    _____

14. a. If you are on a diet, which serving of these foods would you choose to eat?

_____

b. Why?

_____

_____

The energy from burning fuels is used to heat homes, cook food, and operate cars. Some fuels are solid like wood and coal, some are gas like natural gas, and others are liquid like gasoline and kerosene.

The energy stored in fuels is measured in much the same way as the energy content of food. You measure the temperature increase of water produced by burning the fuel. Scientists collect data on various types of fuels so that comparisons can be made among the different types of fuels. The higher the energy content of a fuel, the more heat it produces. Use the Fuel Energy Content chart which follows to answer questions 15, 16, and 17.

Fuel Energy Content

Fuel	Energy Content (Joules per Gram)
coal (solid)	28 000
gasoline (liquid)	44 000
kerosene (liquid)	43 000
methane (gas)	49 000
ethane (gas)	44 000

15. Which fuel provides the most energy for each gram?

_____

16. Which fuel provides the least energy for each gram?

_____

17. Compare the values for fuels and those for foods. In general, which have a higher energy content – foods or fuels?

_____

Check your answers with your learning facilitator.

Activity 2: Mechanical Forces as a Source of Heat

Do you remember the definition of temperature? It is a measure of the average speed of the particles of a substance. If the particles in a substance move more quickly, the substance gets hotter.

Mechanical forces can be used to make the particles of a substance move more quickly. A force is a push or a pull on an object. Pushes and pulls done by a machine or by you are called mechanical forces. Have you ever hit a nail with a hammer several times? If you feel the nail, it has become warm. A moving hammer has energy. When the hammer strikes the nail, the energy is transferred to the object. Part of this energy causes the particles of the nail to move faster. When the particles move faster, the temperature increases. This is an example of how **mechanical energy** can produce heat.

Mechanical energy: energy due to the position or motion of materials

This activity will give you experience with producing heat by using mechanical force. You will use friction, bending, and pounding as examples of mechanical force.

Friction

See Another Effect of Friction on page 167 of *Science Directions 7*. The experiment which follows is based on the information given on that page.

Materials You Need

- brick (or piece of concrete)
- large nail

Steps to Follow

Step 1: Estimate the temperature of the large nail by touching it to the palm of your hand.

Step 2: Rub the end of the nail vigorously against the brick for 10 seconds.

> **Caution**
>
> Do not rub the nail any longer than 10 seconds.

Step 3: Quickly (but carefully) touch the end of the nail to the palm of your hand to feel the temperature.

Questions to Answer

1. What happened to the temperature of the nail?

   _____

2. Predict what would happen if you increased the force of the nail against the brick by pressing harder.

   _____

   _____

3. Give a reason for your prediction.

   _____

   _____

4. Describe a situation where heat produced by friction could be harmful.

   _____

   _____

   _____

   _____

5. Describe a situation where heat produced by friction could be useful.

Bending

Materials You Need

- paper clip

Steps to Follow

Note: See the diagrams under number 2 on page 242 of *Science Directions 7* to help you with this investigation.

Step 1: Straighten a paper clip and feel its temperature by touching it to the palm of your hand.

Step 2: Bend the paper clip back and forth quickly for 10 seconds.

Step 3: Feel the temperature of the region where you bent the paper clip, again by touching it to the palm of your hand.

Questions to Answer

6. What happened to the temperature of the paper clip?

7. Use the particle theory of matter to explain what happened to the temperature during bending.

Pounding

Materials You Need

- wooden block
- hammer

Steps to Follow

7 Science Directions

Note: See the diagrams under number 3 on page 242 of *Science Directions 7* to help you with this investigation.

Step 1: Feel the temperature of the wooden block by holding it in the palm of your hand.

Step 2: Pound one place on the block about ten times with a hammer.

Step 3: Feel the temperature of the block by again holding it in the palm of your hand.

Questions to Answer

8. What happened to the temperature of the block?

_____

9. Give a reason for the change in temperature.

_____

_____

_____

_____

Check your answers with your learning facilitator.

Activity 3: Other Sources of Heat

In Activity 1 you have seen that food and fuels have chemical energy stored in them. Chemical energy is widely used as a source of heat. Heat is released through the chemical process of burning.

Read page 240 of *Science Directions 7* and review Activity 1 for more information on how chemical energy provides heat.

In Activity 2 you saw how mechanical forces are a source of heat. Now you will look at some other sources of heat.

Electricity as a Source of Heat

Electrical energy: energy resulting from the flow of electrons

Electrical energy is used to produce heat in many appliances such as toasters, stoves, hair dryers, irons, and heaters. Electrical appliances which are not designed to produce heat give off heat as a waste. An electric light bulb uses about 5 percent of its energy in producing light and gives off 95 percent of its energy as waste heat.

Electricity is produced by spinning generators. The generators are turned by turbines that are moved by the force of steam or moving water.

The water of large river systems can be stored behind dams. The water is run through tubes to the bottom of the dam where the force of the moving water turns the turbines. Electricity produced by this process is called **hydroelectricity**.

Hydroelectricity: electricity produced from the energy of falling or rapidly flowing water

Another way to make electricity is by burning coal or natural gas to boil water. The steam is then forced through pipes connected to turbines. The steam turns the turbines which spin the generators to produce electricity.

Read page 241 of *Science Directions 7* for more information regarding hydroelectric and coal-fired generating stations.

Are there other ways electricity can be produced?

The plant and animal material in garbage can be burned to produce heat. Garbage can also be used to make fuels called methane and methanol. As supplies of coal and natural gas become more scarce, garbage may become a more common source of heat. The heat could be used to make steam. The steam could then be used to make electricity. The electricity can be used to produce heat at the touch of a switch. This conversion of fuel (chemical energy) to boiling water (heat energy) to moving generators (mechanical energy) to electricity (electrical energy) to heat in a toaster (heat energy) shows that heat is a type of energy that can be changed from and to other types of energy.

Geothermal Energy as a Source of Heat

Read the information on page 243 of *Science Directions 7* on how geothermal energy is used as a source of heat in some parts of the world.

Geothermal energy: the energy inside the Earth

In Canada, because there are so many other sources of heat, **geothermal energy** is not used widely. However, some hot springs in Alberta and British Columbia are used as a source of hot water for swimming pools which are open year-round.

Solar Energy as a Source of Heat

Some energy sources, such as coal and oil, supply heat but are destroyed in the process. However, there are energy sources that can be used to provide heat without being destroyed. For example, you have already seen how some of the electricity that is used for heating purposes is produced from the moving waters of rivers. The water is not destroyed. Another example is sunlight. The energy contained in sunlight can be used to provide heat without being destroyed. The sun is a source of **solar energy**.

Solar energy: the energy contained in sunlight

Read pages 244 and 245 of *Science Directions 7* to find out how the energy from the sun can be captured and used as a source of heat.

1. What are some sources of chemical energy? Name three foods and three fuels that are sources of chemical energy.

   Foods
   - _____
   - _____
   - _____

   Fuels
   - _____
   - _____
   - _____

2. What are the three main sources of electrical energy?
   - _____
   - _____
   - _____

3. Describe two examples in which electrical energy is used as a source of heat.

   - _____
     _____
   - _____
     _____

4. Why is geothermal energy sometimes used as a source of heat?

   _____
   _____
   _____
   _____

5. List several changes that would have to be made to your home in order for you to use solar energy as the major source of heat.

   _____
   _____
   _____
   _____
   _____
   _____
   _____

Check your answers with your learning facilitator.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

The energy contained in fuels and foods is called chemical energy. You can change this chemical energy to heat by burning the fuel or food. Your body is also able to change the chemical energy of food into heat to keep your body at 37°C.

Different fuels and foods contain different amounts of energy. They can produce different amounts of heat.

Electrical energy can also be used to produce heat. Electricity can be made by turning generators. The electricity which flows through wires can be changed to heat by appliances such as a toaster and a hot plate.

Geothermal energy is the heat that the Earth contains. The inside of the Earth is hot enough to melt rock and boil water. Melted rock sometimes finds a way to the surface of the Earth and forms a volcano. Boiling water that reaches the Earth's surface may form a geyser or a hot spring.

Much of the Sun's energy (solar energy) that reaches the Earth is changed into heat. Solar energy heats the air, melts snow and ice, and warms rivers and lakes every day. Solar collectors have been built to store the solar energy for use on cloudy days and during the night.

Mechanical energy is made by moving things. Machines move things and you move things. Friction (surfaces rubbing), bending, and pounding are examples of mechanical energy. The heat caused by the friction of a space shuttle entering the Earth's atmosphere is an example of friction. You can also rub your hands together to produce heat by friction.

Each of the following types of energy are sources of heat:

- chemical energy
- electrical energy
- geothermal energy
- solar energy
- mechanical energy

1. Describe how you could heat water three different ways to make tea. Use a different type of energy for your source of heat for each method.

   - Energy Source: _____
     Method 1

     _____

     _____

     _____

   - Energy Source: _____
     Method 2

     _____

     _____

     _____

   - Energy Source: _____
     Method 3

     _____

     _____

     _____

2. Describe one advantage and one disadvantage for each method.

   a. Method 1
      advantage: _____

      _____

      _____

      disadvantage: _____

      _____

      _____

b. Method 2
advantage: _____

_____

_____

disadvantage: _____

_____

_____

c. Method 3
advantage: _____

_____

_____

disadvantage: _____

_____

_____

Check your answers with your learning facilitator.

Enrichment

You know that heat is the energy transferred from a hot substance to a colder substance. You can measure the amount of energy transferred in units called joules. A joule is an extremely small unit. It takes 4.2 J of heat energy to raise the temperature of 1 g of water by 1°C. So by knowing the temperature change and the amount of water used, you can calculate the number of joules of heat that are transferred from a hot substance to a colder one.

In this enrichment activity you will heat some water with a birthday candle and then heat a second sample of water with a large candle to find out which candle gives off the most heat in 2 minutes.

Caution

This activity is to be done under
the supervision of the learning facilitator.

Materials You Need

- birthday candle
- large candle
- two empty pop cans
- thermometer
- oven mitt
- timer
- graduated cylinder or measuring cup
- water

Steps to Follow

Step 1: Measure 100 mL of water into an empty pop can.

Step 2: Measure and record the starting temperature of the water in the pop can.

Step 3: Light the birthday candle. Hold the pop can of water over the flame so that the top of the flame just touches the bottom of the can.

Step 4: After 2 minutes, blow out the flame and measure the temperature of the water. Record this final temperature of the water.

Step 5: Repeat steps 1 to 4 using the other pop can and the large candle. Record your measurements in the chart.

Observations

Type of Candle	Starting Temperature (°C)	Final Temperature (°C)
birthday		
large		

Interpretations

100 mL of water were heated by each candle. Every millilitre has a mass of 1 g. This means that each candle heated 100 g of water.

1. Since it takes 4.2 J of heat energy to raise the temperature of 1 g of water by 1°C, how many joules of heat energy would be needed to raise the temperature of 100 g of water by 1°C?

2. Check your observation chart. The temperature of the water in each sample likely increased by more than 1°C. Find the temperature change in each case by subtracting the starting temperature from the final temperature.

   a. change in temperature for birthday candle _____

   b. change in temperature for large candle _____

3. To calculate the number of joules of heat that are transferred from each candle to the 100 g samples of water, you need to multiply the answer you obtained for question 1 by the changes in temperature you obtained for question 2.

   a. Show the calculations for the birthday candle.

   b. Show the calculations for the large candle.

4. How many joules of heat did the birthday candle transfer to the water in 1 minute?

5. How many joules of heat did the large candle transfer to the water in 1 minute?

6. Describe how you could calculate the number of joules of energy that 1 gram of the large candle contains.

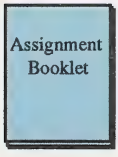
Check your answers with your learning facilitator.

Conclusion

For thousands of years, humans have been concerned with ways of producing heat for both cooking and warmth. In this section you have learned ways that heat can be produced from chemical, mechanical, electrical, solar, and geothermal energy.

You compared the energy content of fuels and foods by measuring the increase in temperature the fuel or food can create when burned to heat water. Scientists collect data and then make comparisons among the various fuels and foods. These comparisons help you make wise decisions in nutrition and in choosing a fuel.

Each source of heat has advantages and disadvantages. You should consider these when you are deciding which source of heat to use.



ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 4.

MODULE SUMMARY

Many people think that temperature and heat are the same thing. In this module you have learned about the differences between temperature and heat. You should know about the following:

- The three states of matter are solid, liquid, and gas.
- A thermometer is a device used to measure temperature. The unit for temperature is degrees Celsius (°C).
- Heat and temperature are different. Heat is the amount of energy transferred. Temperature is the average speed of the particles of a substance.
- Heat moves from a warm substance to a cooler substance.
- The particle theory of matter is useful in explaining the effect of heat on solids, liquids, and gases.
- The energy content of foods and fuels can be measured in units called joules (J).
- Sources of heat include chemical, mechanical, electrical, geothermal, and solar energy.

Appendix

Glossary

Bimetallic strip
- two strips of different metals bonded together

Calibrate
- to mark a scale of units on a measuring device; such as degrees on a thermometer

Chemical energy
- the energy stored in food and fuel

Clinical thermometer
- a thermometer that is used to measure body temperature

Compressed
- squeezed; pushed together

Contract
- to decrease in volume

Electrical energy
- energy resulting from the flow of electrons

Energy content
- the amount of energy contained in a substance
  Energy content may be measured in joules per gram (J/g).

Expand
- to increase in volume

Gas
- a state of matter that has no definite shape or volume
  A gas takes the shape of its container and spreads out to fill the container it is put in. Air is a gas.

Geothermal energy
- the energy inside the Earth

Heat
- the energy transferred from a hot substance to a colder one

Hydroelectricity
- electricity produced from the energy of falling or rapidly flowing water

Joule
- unit for measuring energy; the amount of energy that would be required to raise a 100 g mass 1 m

Liquid
- a state of matter that has a definite volume but no definite shape

Melted
- the change of state from solid to liquid

Mechanical energy
- energy due to the position or motion of materials

Particle theory
- the theory that all matter is made up of tiny particles that are always moving

Solar energy
- the energy contained in sunlight

Solid
- a state of matter that has a definite volume and shape
  Wood is a solid.

State of matter
- one of three states (gas, liquid, or solid) that all substances can be grouped into

Temperature
- a measurement of the average energy of a substance, or how hot or cold it is
  According to the particle theory of matter, the particles of a substance move faster if the temperature is higher.

Theory
- a hypothesis that has been supported by experiments done by many scientists

Thermocouple
- a device that uses electricity to measure temperature

Thermometer
- a device to measure temperature

Thermostat
- a device that measures the temperature in a room or an appliance and turns the furnace or appliance on or off to keep the temperature at a desired point

Uncalibrated
- without a numerical scale

Volume
- the amount of space occupied by a solid, liquid, or gas; the amount of space in a container

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